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BULLETIN

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OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

MEXICO MEETING

AT

MEXICO, D. F., MEXICO

JUNE 21–23, 1950

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JUNE 21, 1950 Vol. 25, No. 4

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

MEXICO MEETING, JUNE 21–23, 1950

THE 300th recurrence of almost anything invites a special celebration; and the scene of the **300th meeting of the American Physical Society** will be the most southerly, the most altitudinous, the most foreign, the most exotic, and in many ways the most interesting city and country in which we shall ever have met or are at all likely to meet. From any other locality our members tend to disappear with incredible speed as soon as or before the meeting is over; here they will be disposed to linger, and they will find much to delight them in a country of diverse and wonderful beauty tenanted by a civilization contrasting amazingly with that of the United States. This is no place to write at length about the sights of Mexico: one should prepare as one would for a trip to Europe, i.e., by getting a guidebook and reading up the history of Mexico. Knowledge of the Spanish language is unnecessary, but the more one learns of it the more one will benefit by the journey.

The **dates of the meeting** are Wednesday, Thursday, and Friday, June 21, 22, and 23, 1950. The Inaugural Session will commence at eleven on Wednesday morning. Afternoon and evening sessions, conforming with Mexican custom, will begin at later hours than in the United States; these hours are specified in the Bulletin according to the twenty-four hour schedule, familiar to travelers on the Continent of Europe. This meeting replaces both of the Summer Meetings which are normally held in the East and the West, respectively, of the United States. This is fitting, as the meridian of Mexico City is midway between those of Philadelphia and San Francisco.

Meeting-places. The Inaugural Session will be held in one of the most spectacular buildings of Mexico, the Palacio de Bellas Artes at the foot of Avenida Juarez (even the most elementary map will show it). The Symposium and the sessions of invited papers will be housed in the Anfiteatro Bolívar in Calle Justo Sierra. The sessions of ten-minute papers will be held in various lecture-rooms of the Palacio de Minería, a superbly beautiful eighteenth-century building at 5, Calle de Tacuba, east of the Alameda. When two or three simultaneous sessions are assigned to the Minería, the hall allotted to each will be shown by posters in or near the doorway. The open court of the Minería will be found an admirable place for informal meetings and conversation.

The **registration desk** will be located, on Wednesday morning and only on Wednesday morning, at the main entrance of the Palacio de Bellas Artes. Thereafter it will be found in the Palacio de Minería. Office hours will be 9 to 13 and 15 to 18. Members who intend to use it for the delivery of mail or telegrams should tell their correspondents to address them at Sociedad Americana de Física, Palacio de Minería, Tacuba 5, Mexico, D. F., Mexico. "Employees in charge of the registration desk will be provided with city and road maps, plane, railroad, and bus timetables, etc., and will endeavor to provide reliable information on miscellaneous matters."

A **Symposium on Cosmic Rays** will be held in the Anfiteatro Bolívar on Thursday morning and Thursday afternoon; the choice of topic is due partly to the intrinsic interest of this rich and rapidly growing field, partly to the fact that it is cultivated by Mexican physicists. The speakers will be more numerous than is the custom at meetings in the United States, and the individual allotments of time correspondingly smaller; yet the limits of available time debarred us from inviting still others who would have been welcome participants in this Symposium.

Nuclear accelerators and some of their achievements will be the topic of three invited papers on Wednesday afternoon. The cyclotron at Nevis, the greatest now in operation, will make its debut before the Society through a report by E. T.

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Booth. S. K. Allison will speak of the work and the equipment of the Institute of Nuclear Studies at the University of Chicago, mentioning *inter alia* the dating of archaeological specimens by carbon 14, a topic of peculiar interest in the ancient land of Mexico. E. M. McMillan will speak of the production of artificial mesons.

On Friday there will be several invited papers on a variety of topics. Jose Mireles Malpica will describe a 300-kv electrostatic direct-current transformer which is being used in industrial radiography. R. A. Millikan will speak of the evolution of modern physics; Benno Gutenberg of low velocity layers in earth, ocean, and atmosphere; Frederick Seitz on lattice imperfections and plastic flow in metals; Nabor Carrillo on soil mechanics of the City of Mexico; W. V. Houston on certain phenomena exhibited by supra-conductive substances; and Ray Pepinsky on modern methods of x-ray crystal analysis.

On Wednesday and Thursday evenings there will be public lectures at 21 o'clock in the Anfiteatro Bolívar. On Wednesday, Karl K. Darrow will speak, under the title "El átomo desde Lucrecio hasta ahora," in an approximation to Spanish which it is hoped will afford more amusement than pain to the Mexicans present. On Thursday Donald H. Menzel will speak in Spanish under the title "El sol y el universo," and will show some of his celebrated movies of solar eruptions.

Eighty-eight contributed papers are distributed among nine sessions in various halls of the Palacio de Minería; none coincides in time with the Inaugural Session. Among these, Session G will comprise papers on gravitation and relativity by some of our Mexican colleagues, and will commence with invited papers on Theories of Gravitation by H. P. Robertson and on A Perfectly Symmetrical Universe in Flat Space-Time by Carlos Graef Fernandez.

The **banquet of the American Physical Society** (informal dress!) will be held on Friday evening at 20 o'clock in the Salón de los Candiles of the Hotel del Prado. It will be followed by after-dinner speeches by Manuel Sandoval Vallarta and by E. U. Condon. The price is expected to be forty pesos (about five U. S. dollars) including wines and tips. The Local Committee would like to form an advance estimate of the number to be expected; please therefore fill out and send, by AIR MAIL, the form on the inside back cover page of this Bulletin. The tickets will be sold at the registration desk. Obviously they should not be mailed.

Travel instructions were distributed at the end of April to all members of the Society. It would be pointless to repeat them here, as the Bulletin will not be distributed early enough to make repetition worth while. If any member makes up his mind to go only after he receives the Bulletin, he should rush to a travel agency and see whether they can get him transportation and room reservation. In the improbable event that he gets the Bulletin early enough for his letter to reach Mexico City before June fifteenth, he should write to the hotel of his choice, mentioning that he is coming to our meeting and giving his dates of arrival and departure. Get your tourist card at a Mexican consulate before you start; if you forget this up to the last minute, bring along your birth certificate and try to get the tourist card at the border.

Health. Foreigners in Mexico must take precautions if they are to escape ailments which, while usually transient, are capable of hampering their activities. It is wise to quit drinking water (except bottled water) and milk as soon as you cross the frontier; this includes other liquids when mixed with water or ice or milk. There are indeed various brands of pills which are said to make it safe to indulge in water; we have no information about these. Beer (which is of excellent quality in Mexico) and black coffee may substitute for water. Avoid also salads, fruits other than those which you peel yourself, and uncooked foods generally. *Vaccination is imperative;* get it done before you leave home, and bring the vaccination certificate along to show at the border *both going and coming*. Anti-typhoid inoculation is recommended. The altitude of Mexico City (somewhat over 7000 feet), which compels some people to walk and climb stairs slowly, has no apparent effect on others.

The **Council** of the American Physical Society will meet in the Palacio de Minería (the room will be indicated by a poster) on Friday at 16:30.

Post-deadline papers of exceptional importance will be considered for presentation if delivered not later than June 16 to Karl K. Darrow, Hotel Maria Cristina, Lerma 31, Mexico, D. F., Mexico. Those which are accepted (if any) will be scheduled for presentation at the end of Session L. Do not send in a post-deadline paper unless you intend to come to the meeting regardless of whether it be accepted. Abstracts will not be printed.

Prospective meetings of the Society are scheduled to be held at Chicago, November 24–25, 1950; New York, February 1–3, 1951; Pittsburgh, some time in March, 1951; and Washington, April 26–28, 1951. The next Winter Meeting on the Pacific Coast will be held at the University of California, Los Angeles, on December 28–30, 1950.

General Rules Relating to Papers

The time allowed for the presentation of a contributed paper is ten minutes at most. With respect to those which appear in the "supplementary programme" the Chairman of the session indicated in a footnote to each paper is empowered to reduce its allotment of time to less than five minutes or to read it by title. (These are the papers of which the authors have other papers on the regular programme.)

The abstracts of the papers contributed to the Mexico meeting, which follow hereinafter, will be reprinted in *Physical Review* exactly as they stand here. The procedure for submission of errata is described in the Washington Bulletin and in the Oak Ridge Bulletin; the errata must be received by Miss Ruth Bryans, 57 East 55th Street, New York 22, New York, not later than July seventh. The type cannot be altered to even the slightest extent without forfeiting the economies for the sake of which the new policy has been adopted. *Under no circumstances send* your original abstract to Miss Bryans with alterations marked upon it; write out the errata (examples, far too numerous, can be found in *Physical Review*).

Speakers must retrieve their lantern-slides before leaving the hall in which their papers were given. The Local Committee is under no obligation to keep or to return them. They cannot be mailed back across the border.

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

EPITOME OF THE MEETING

(Personal names are those of invited speakers.)

Wednesday Morning

A. Inaugural Session. President Alemán, President Garrido, President Rabi. Bellas Artes.

Wednesday Afternoon

B. Booth, Allison, McMillan. Anfiteatro Bolívar.
C. Solid-state physics. Minería.

Wednesday Evening

Darrow. Anfiteatro Bolívar.

Thursday Morning

D. Nuclear instrumentation, beta-emitters, Minería.
E. Symposium on cosmic rays, first session: Vallarta, Winckler, Menzel, Ney, Bradt, Salant. Anfiteatro Bolívar.

Thursday Afternoon

F. Symposium on cosmic rays, second session: Schein, Brode, Anderson, Fretter, Korff, Leighton. Anfiteatro Bolívar.
G. Robertson, Graef Fernandez; gravitation, relativity, theoretical physics. Minería.
H. Mostly electron physics and optical physics. Minería.

Thursday Evening

Menzel. Anfiteatro Bolívar.

Friday Morning

I. Malpica, Millikan, Gutenberg, Seitz. Anfiteatro Bolívar.
J. Gamma-rays and neutrons. Minería.
K. Cosmic Rays, I. Minería.

Friday Afternoon

L. Cosmic Rays, II; atmospheric physics. Minería.
M. Carrillo, Houston, Pepinsky. Anfiteatro Bolívar.
N. Artificial mesons; miscellany in nuclear physics. Minería.
O. Nuclear theory. Minería.

Friday Evening

Banquet of the American Physical Society; Vallarta, Condon. Hotel del Prado.

PROGRAMME

WEDNESDAY MORNING AT 11:00

Palacio de Bellas Artes

(I. I. RABI presiding)

Inaugural Session

A1. Opening of the meeting by DR. MIGUEL ALEMÁN, *President of the Republic of Mexico.*
A2. Address of welcome on behalf of the Universidad de México by LUIS GARRIDO, *President of the Universidad de México.*
A3. Response by I. I. RABI (*Columbia University*), *President of the American Physical Society.*

WEDNESDAY AFTERNOON AT 15:00

Anfiteatro Bolívar

(C. C. LAURITSEN presiding)

Invited Papers on Accelerators and Artificial Mesons

B1. Report on the Cyclotron at Nevis. E. T. BOOTH, *Columbia University.* (40 min.)
B2. The Experimental Programme of the Institute for Nuclear Studies at the University of Chicago. S. K. ALLISON, *University of Chicago.* (40 min.)
B3. Artificial Production of Mesons. E. M. MCMILLAN, *University of California, Berkeley.* (40 min.)

WEDNESDAY AFTERNOON AT 15:00

Minería

(F. SEITZ presiding)

Solid-State Physics

C1. Superconducting Niobium Nitride at Microwave Frequencies.* MAX BODMER, JEAN V. LEBACQZ, AND D. H. ANDREWS, *The Johns Hopkins University.*—The operation of a NbN bolometer as a detector of radiofrequency signals has been reported in a previous paper.[1] The work has now been extended to frequencies in the 10,000-mc band using a cryostat which maintains the operating temperature, −259°C, for about seven hours. The impedance of the bolometer is only about one ohm, and a special tuner, adjustable inside the vacuum, matches this impedance to that of a standard 3-cm wave guide. Because of the high transformation ratio, the band width of the tuner is only about 10 mc. With this equipment, both a bolometer action and a detection action were observed in demodulating the microwave energy.

* Assisted by the ONR.
[1] Lebacqz, Clark, Williams, and Andrews, Proc. I. R. E. **37**, No. 10, 1147 (1949).

C2. Perturbation Treatment of Heisenberg's Model of Ferromagnetism.* H. EKSTEIN, *Armour Research Foundation.*—The Slater-Bloch equations for the exchange interaction between N atoms of spin $\frac{1}{2}$ can be written under the form of a wave equation describing the distribution of r fictitious particles (the reversed spins) over N lattice sites. The Hamiltonian includes repulsive and attractive forces. For consistency, in order to obtain the correct number of eigenvalues, it is necessary to prescribe Fermi-statistics for the "particles." At the same time, this convention takes into account rigorously the repulsive forces, i.e., the impossibility of two reversed spins occupying the same lattice point. When the energies obtained by first-order perturbation calculus are introduced into the partition sum, they yield an implicit equation for the magnetization as a function of temperature and field, similar to the Weiss equation. For low temperatures, Bloch's $T^{\frac{3}{2}}$ law is obtained, but the slope of the M-T curve becomes infinite at the Curie point. For a simple cubic lattice, the Curie point is at $kT_c \sim 2J$. For the linear chain, the relative number of reversed spins at $T=0$ is of the order $\frac{1}{r}$, contrary to Bloch's result $r \to \infty$. For the two-dimensional lattice, one obtains ferromagnetism.

* Work supported by ONR.

C3. Further Observations on Domain Fringe Fields. L. MARTON, J. A. SIMPSON, AND A. VAN BRONKHORST, *National Bureau of Standards.*—The previously reported fringe field observations on a single cobalt crystal were continued and extended. Identification of the domain boundaries by means of

powder patterns allows us to orient the crystal in the proper direction for optimum observation of the electron optical shadow pattern. Quantitative data on the field distribution in the equatorial planes between domain walls in the 100 plane of the crystal shall be communicated. Experiments were carried out also on colloidal Ni and Fe particles. For the purposes of that type of work, the instrument was modified to operate at higher magnifications. In the case of such colloidal particles, no attempt was made to measure the field quantitatively. The effort was directed towards resolving the problem of whether such particles contain one, two, or four domains.

C4. Anomalous Diamagnetism of Graphite. S. MROZOWSKI, *University of Buffalo.*—The relation of the diamagnetism of aromatic molecules to the diamagnetism of graphite is explained in terms of a variable energy gap between the filled and empty (conduction) bands. Experimental data show that the anomalous component of the molar susceptibility of aromatic molecules due to a quantized motion of electrons around the benzene rings is roughly proportional to the number of benzene rings in the molecule. The diamagnetic contribution of these filled energy levels is independent of temperature, and represents only a small part (1/13.5) of the susceptibility of large graphite crystals. In large aromatic molecules the energy gap becomes small enough for electrons to be activated into the conduction band thus giving rise to a diamagnetism of free electrons and holes. This temperature dependent component increases with increase of molecular dimensions (increase of the effective number of electrons) up to the value corresponding to an infinitely large graphite crystal. The susceptibility of graphite can be explained quantitatively in terms of Landau diamagnetism as was done by Ganguli and Krishnan, modifying however their assumptions in accordance with Wallace's analysis of electronic motions in the graphite lattice.

C5. The Self-Diffusion of Cobalt in Gelatin as Measured with Co^{60}.* HERMAN BRANSON AND WOODFIN LEWIS, *Howard University.*—The self-diffusion coefficient of cobalt in gelatin gel was measured at 5°C by permitting the gelatin blocks with equal concentration of $Co(NO_3)_2$ to lie in contact for different times ranging from 72 to 600 hours. The lower block contained a trace of Co^{60}. The self-diffusion coefficient was found to vary slightly with time averaging 1.73×10^{-6} cm²/sec. The analyses were made on 1 mm sections of the blocks into which the Co^{60} diffused. The experimental values are discussed in terms of the models for diffusion in binary alloys presented by Seitz and Bardeen. It is shown that the values are consistent with a mechanism which assigns a "brush-heap" structure to the gel with the Co ions moving from position to position by a place-exchange process. The Einstein-Stokes equation gives an abnormally small value for the radius of the diffusing particle. The activation energy with the above value of D according to the Frenkel theory is $q\sim2kT$.

* Assisted by the ONR and Research Corporation of New York.

C6. Frequency Factor and Activation Energy for the Volume Diffusion of Metals.* G. J. DIENES, *North American Aviation, Inc.* (Introduced by M. M. Mills).—The theoretical equations proposed for calculating D_0 of the diffusion-constant-temperature relation $D=D_0e^{-E/RT}$ are critically discussed in the light of presently available data. It is concluded that none of the relations gives satisfactory agreement with experiment. Empirical analysis of experimental data covering a wide range of D_0 and E values showed that the quantity E/T_m, where T_m is the melting point in °K, is the main factor in determining the value of D_0, and that D_0 depends approximately exponentially on E/T_m. In addition to many other diffusion constants, it is shown that the anisotropic diffusion of zinc and the widely differing diffusion constants for self-diffusion in α- and γ-iron are included in the proposed empirical correlation. A possible theoretical basis for the empirical correlation is described based on the idea of local melting or disordering. The quantity E/T_m is identified with the entropy of activation.

* This document is based on work performed under Contract for the AEC.

C7. The Rate of Diffusion of Gold into Copper at Low Gold Concentrations.* A. B. MARTIN AND FRANK ASARO, *North American Aviation, Inc.*—The rate of diffusion of small concentrations of gold into copper has been measured by the radioactive tracer method. Radioactive gold was electroplated on the ends of small polycrystalline copper rods and the samples annealed at temperatures between 750°C and 1000°C. The penetration of gold was determined by sectioning in a lathe, the chips from each cut being collected, weighed, dissolved in acid, and the activity measured with an immersion Geiger counter. The data have been analyzed assuming D to be independent of concentration. The variation of D with temperature is described by $D=Doe^{-Q/RT}$, with $Q=44{,}900\pm1300$ cal./mole and $Do=0.1\pm0.06$ cm²/sec. (least squares fit). Although the data are not sufficient at the present time to permit a detailed quantitative analysis of the various factors which influence the measured values of the diffusion coefficients, it appears that Q and Do are constant within the statistical reliability of the results for (1) gold concentrations from 0.001 to 1.0 atom percent, (2) copper purity from 99.999 percent to 99.95 percent, and (3) grain sizes having mean linear dimensions up to 1.0 mm.

* This paper is based on work performed under Contract for the AEC.

C8. Effect of High Energy Neutron Bombardment on Crystal Lattice of Beryllium, Graphite, Diamond, and Aluminum.* S. S. SIDHU AND C. O. HENRY, *University of Pittsburgh.*—Powdered samples of beryllium, graphite, diamond, and aluminum were bombarded for periods of about 10, 20, and 30 hours with neutron flux of 6.4×10^8 neutrons/sec./cm²/microampere of deutron current. The flux was obtained from Be(d,n) reaction with deutron energy of 15 Mev from the University of Pittsburgh Cyclotron. The energy corresponding to the maximum intensity in the hetrogeneous beam of neutrons was approximately 3 Mev. X-ray diffraction patterns of the samples were made before and after the bombardment, and the diffraction data obtained from these patterns were compared. Marked changes were observed in some of the lattices. These results will be reported.

* This research was supported in part by ONR.

C9. The Photography of Atoms in Crystals.* In the ordinary simple microscope, the same light is permitted to flow through the entire system. A more general microscope can be devised in which light of one wave-length is permitted to flow as far as the diffraction image of the object, then light of a second wave-length is substituted at this plane, and continues to flow through the rest of the optical system. It is shown that for such a generalized microscope, the magnification depends not only on the ordinary image-to-object distance ratio, but also on the ratio of wave-lengths used. Utilizing x-rays and visible light, this second factor is about 10^4 diameters, and the whole magnification is of the order of 3×10^8. This is enough to permit one to see an atom. Apparatus has been built which realizes this theory. A most important characteristic of any such system is that a loss of phase occurs at the first diffraction image, where the wave-length substitution takes place. This phase must be supplied by the apparatus. It is accomplished with the aid of phase shifters prepared from a large uniform mica cleavage fragment. The apparatus and the results achieved with it are described.

* Author unknown. This is presumed to be a case in which the author put his name and address only in the covering letter, which was destroyed before the omission of these data from the abstract was perceived.

C10. X-RAC and the Feasibility of Automatic Crystal Structure Analyses.* RAY PEPINSKY, *The Pennsylvania State College.*—X-RAC, the analog computer for crystal structure analysis, generates a two-dimensional density function involving up to 820 Fourier coefficients in less than one second. All centro-symmetric functions corresponding to complete permutations of 20 phases, e.g., or 2^{20} syntheses, can thus be generated and recorded in a few hours. These syntheses can be automatically examined for maximum and minimum excursions, number of maxima, molecular symmetry, possible knowledge of the density function in certain regions, etc., and acceptable syntheses and corresponding phases recorded in this time. Guidance as to choice of terms for such phase permutation can be obtained from phase-limiting equalities and inequalities arising from positiveness, upper limits, atomicity, etc. The number of terms required for a synthesis is reducible through application of artificial temperature factors of various strengths, and choice of most significant coefficients can be made through examination of correspondence between Patterson syntheses formed from a restricted number of terms and from the complete array of terms. Further approaches to automatic determination are possible via the X-RAC structure-factor computer. Atomic coordinates are established in this by d.c. voltages. These can be modulated until agreement between calculated and observed factors is simultaneously obtained at a number of reciprocal lattice nodes.

* Development supported by ONR.

C11. Low Temperature X-Ray Diffraction Goniometer.[1] B. C. FRAZER AND RAY PEPINSKY, *The Pennsylvania State College.*—A low temperature x-ray goniometer has been constructed for single crystal studies at temperatures of liquid air and below, and specifically for investigations of ferroelectric crystals below their Curie points. The instrument is similar in its basic features to a design by Helmholtz,[2] but the incorporation here of an adjustable arc goniometer and convenient translatory adjustments permits ordinary single-crystal techniques. Standard oscillation, Weissenberg, or precession camera methods may be used. The crystal is cooled by conduction through a copper mount at the base of the liquid air chamber of a demountable stainless steel Dewar. Surrounding the crystal and completing the outer wall of the Dewar is a removable glass bulb drawn down to a thin-walled tube in the immediate vicinity of the crystal. The crystal is irradiated through the thin-walled tube and is rotated in the beam by rotation of the Dewar. Vacuum is maintained during operation by continuous pumping. Details of construction and operation of the instrument and the modifications necessary for use with liquid hydrogen are discussed.

[1] Development supported by Signal Corps Engineering Laboratories.
[2] L. Holmholtz, J. Chem. Phys. 3, 740 (1935).

C12. Performance of Cadmium Sulphide as a Detector of X-Radiation. JOHN E. JACOBS,* *General Electric X-Ray Corporation* (Introduced by Richard W. Jones).—CdS crystals were irradiated with 1.54A pulsating x-radiation and the a.c. component of crystal current was measured. The very long delay in reaching steady state conditions observed when the d.c. component is measured was eliminated by this means. When a secondary illumination of constant magnitude is applied to the crystal while it is irradiated with pulsating X-rays it is found that the characteristics of the crystal are altered greatly. Green light increases the yield while red and blue light decreases the yield. Crystals having lattice defects as evidenced by asterism in Laue patterns were found to have random noise currents as well as to exhibit erratic multiplication processes. Crystals have been subjected to total quanta exceeding 10^{12} with no apparent change in characteristics. It is necessary to irradiate the region adjacent to the negative electrode to achieve maximum output currents. If the x-ray beam is confined to a narrow region adjacent to the negative electrode, blocked for a period and suddenly applied, a current in excess of the steady state value is observed. This effect is modified by use of a secondary illumination.

* Work carried out at Northwestern University.

WEDNESDAY EVENING AT 21:00

Anfiteatro Bolívar

(MANUEL SANDOVAL VALLARTA presiding)

El átomo desde Lucrecio hasta ahora. KARL K. DARROW, *Bell Telephone Laboratories.*

(Conferencia popular)

THURSDAY MORNING AT 10:00

Minería

(A. C. G. MITCHELL presiding)

Nuclear Instrumentation; Beta-Emitters

D1. Electrostatic Direct Current Transformer of 300 Kilovolts.* JOSE MIRELES MALPICA, *Instituto Politecnico Nacional.*—A search for a source of d.c. high voltage for the acceleration of electrified particles led to the Direct Current Electrostatic Transformer. A rotating dielectric transfers electrical energy from a primary to a secondary circuit. A

pair of metallic brushes with the moving dielectric between them and connected to a d.c. source of high voltage, constitutes the primary circuit. The charging current is passed to the surface of the dialectric by corona. When the charged region reaches the secondary brushes, a potential difference approaching the primary voltage is set up between them. In the 1 to 1 d.c. electrostatic transformer the secondary current is given by the following relationship: $i=S(E_p-E_s)\times C_a dA/dt$, where: S is a function of the corona conduction conditions, E_p primary voltage, E_s secondary voltage, C_a capacity per unit area, dA/dt rate of change of area per unit time. Since the primary and secondary circuits are conductively independent, several disks can be placed on a shaft with the primaries in parallel and the secondaries in series, raising the voltage. The 1 to 9 ratio experimental 300 kilovolt electrostatic transformer is used for industrial radiography and is a step in the construction of a one million volt transformer.

* This paper will be given as an invited paper in Session I.

D2. Synchrotron-Oscillation Resonance. NELSON M. BLACHMAN, *Brookhaven National Laboratory.**—Although detrimental betatron-oscillation resonances in a synchrotron have been studied,[1] synchrotron-oscillation resonance has received less attention. The latter's frequency is much lower than the former's, varying from 2620 to 1800 c.p.s. in the Brookhaven proton synchrotron, and resonance may occur with power-supply harmonics. The Brookhaven magnet is powered by a nominally 60-cycle generator and 12-phase rectifier having significant output components at multiples of 720 c.p.s.; the third gives cause for concern. The corresponding ripple of the magnetic field is extremely small because of the magnet's inductance; yet a large synchrotron oscillation may result, losing much of the beam. An extremely small ripple or noise modulation in the accelerating frequency, if present, would have a similar effect; the synchrotron is less sensitive to amplitude modulation. The effect of the magnetic-field ripple, if not filtered out, may be corrected by introducing compensatory a-m or f-m. Such f-m will be introduced by the system which continuously produces the proper frequency for the magnetic field, though some error may be present. The fall in the synchrotron-oscillation frequency with increasing amplitude also helps by its detuning effect.

* Work done under the auspices of the AEC.
[1] E. D. Courant, J. App. Phys. **20**, 611 (1949); D. M. Dennison and T. H. Berlin, Phys. Rev. **69**, 542, and **70**, 764 (1946); N. M. Blachman and E. D. Courant, Rev. Sci. Inst. **20**, 596 (1949).

D3. The Axial Motion of an Electron in a Constant Wave Velocity Section of a Linear Accelerator. DAVID CAPLAN AND EDWARD AKELEY, *Purdue University.*—The relativistic differential equations for the axial motion of an electron in a wave guide, excited by a progressive sinusoidal longitudinal electric wave of constant $\beta \leq 1$, have been integrated. The first integral yields the results of Slater, and gives the energy phase relationship, which is periodic. A second integration yields the phase-distance relationship, and thus completes the determination of the orbits. All separatrices, and the special case of $\beta=1$, are exactly integrable in terms of trigonometric and hyperbolic functions, while the general case requires elliptic integrals of the first and third kind. The former are obtainable from tables, while the latter are evaluated by series expansions, or in the case of particles near the crossing point of the separatrices where the convergence is slow, by the use of the addition theorem for elliptic functions of the third kind. Families of complete orbits in the form of energy-distance and time-distance graphs will be shown for $\beta=0.7$ and 0.97. These are applied to the proposed new Purdue accelerator, which is to consist of three constant wave velocity sections corresponding to $\beta=0.7$, 0.97, and 1, respectively.

D4. The Longitudinal Motion of Electrons in a Linear Accelerator. THOMAS KEENAN and EDWARD AKELEY, *Purdue University.*—Using a modification of a method previously reported,* the energy and phase of electrons moving on the axis of an accelerator have been determined as a function of the distance along the axis. A synchronous particle is defined for the progressive wave case, and the deviations of the energy and phase of an actual electron for both the progressive and standing wave cases from that of the synchronous are expressed as power series in the initial values of these deviations. The coefficients in these expansions are power series in the amplitude of the force acting on the particle. Both expansions have been computed through second-order terms. The computations have been made for a class of accelerators in which the initial energy of the synchronous particle is 50 kev, while its phase relative to the wave is variable. Graphs have been drawn in the progressive wave case for various values of (1) phase of synchronous particle relative to wave, and (2) initial deviation of phase of actual particle relative to synchronous one. In certain cases, corresponding standing wave graphs have been made.

* Hoffman and Akeley, Phys. Rev. **77**, 761, 1950.

D5. Krypton Bombardments: Radioactive Rb 84. WALTER C. BECKHAM* AND M. L. POOL, *Ohio State University.*—Krypton, in an internal gas container, was bombarded with 20-Mev alpha-particles and 10-Mev deuterons. The interior of the container was washed after bombardment with dilute HCl to recover transmutation products. The Rubidium fraction from the deuteron bombardment showed a 38-day half-life. The same activity was obtained by the α+Br reaction. Histograms show that β^+ and β^- are both emitted by this 38-day activity with the number of $\beta^+/\beta^-=6.2$. An end-point energy of 1.3 Mev was obtained by absorption measurements. A gamma-ray of 0.8 Mev is also present. K-capture is inferred from the observed X-rays. Based upon the mode of production and the characteristic radiations emitted the 38-day activity is clearly assigned to Rb 84. The strontium fraction of the Kr+α bombardment shows three position emitting activities which have not yet been assigned mass numbers.

* Lt. Col. U. S. Air Force.

D6. Characteristic Radiations of Rhodium (105).* C. E. MANDEVILLE AND E. SHAPIRO, *Bartol Research Foundation.*—The 36.8-hr. rhodium (105) was grown from its short-lived ruthenium parent when metallic ruthenium was irradiated by neutrons in the Oak Ridge pile. The target material was purified prior to irradiation by the distillation of RuO_4 from a perchloric-sulfuric acid solution of $RuCl_3$. Chemical separations for the removal of ruthenium and technetium were carried out subsequent to exposure. The beta-rays have a maximum energy of ~0.6 Mev as measured by aluminum absorption, and the gamma-rays were found to have an energy of 0.30 Mev when absorbed in lead. The beta-gamma coincidence rate is independent of the beta-ray energy, and the magnitude suggests that the harder beta-rays are coincident with soft quanta of the x-ray region. Very few beta-rays are coincident with the gamma-ray at 0.30 Mev. No beta-beta coincidences were detected for ranges exceeding 6 mg/cm². No gamma-gamma coincidences were found.

* Assisted by the joint program of the ONR and the AEC.

D7. Excitation Function for the 6.7-hr. Cd^{107} by (p,n) and $(d,2n)$ Reactions from Ag^{107}. D. N. KUNDU AND M. L. POOL, *Ohio State University.*—A stack of Ag foils (each 0.3 mil thick) was bombarded with 5-Mev protons and 10-Mev deuterons within a special target. The stack was shielded on all sides except for a small slot for the entry of the beam. From the activities measured up to thicknesses far beyond the range of the bombarding particle, the excitation function for the 6.7-hr. Cd^{107} was constructed. The thresholds for the $Ag^{107}(p,n)$ and $Ag^{107}(d,2n)$ reactions were at 3.15 and 4.50 mils respectively. The (p,n)-curve dropped steeply by a factor $\sim 10^{-6}$ from the first to the 10th foil beyond which it could not be traced. The proton resonance peaks expected in the light of recent reports[1] are, therefore, not observed. The resonance peaks for the 6.7-hr. activity reported from secondary protons in deuteron bombardments, were also looked for but not found. The presence of proton resonance peaks should have been observed more clearly in this straight proton bombardment than in one where the protons have to result from a primary deuteron reaction. In the deuteron bombardment, the 13-hr. Pd^{109} was again quite high in the front foils as compared to that resulting from the (n,p) reaction alone.

[1] C. Chamie, J. de Phys. et Rad. **11**, 77 (1950).

D8. Gamma-ray Spectrum of the 2,3 Day Isomer of Cadmium 115*. E. BROCK DALE AND J. D. KURBATOV, *Ohio State University.*—Cadmium metal was activated by neutrons in Oak Ridge National Laboratory and was studied with a thin lens gamma-spectrometer. In addition to K and L photoelectron-peaks produced by the 336 ± 1 kev gamma-ray, photoelectrons of energies of 434 ± 1 kev and 506 ± 2 kev were found. These photoelectrons correspond to a gamma-ray, 522 ± 2 kev. It has been observed that the 522 kev gamma-ray, prompt transition in indium 115, follows the 2.3 day isomer of cadmium 115.[1] The 336 kev gamma-ray is emitted by the metastable state, $T_{\frac{1}{2}}=4.5$ hr., of indium 115 as had been established previously. Less intense peaks of photoelectrons of lower energy than 0.5 Mev were also found in the 2,3 day cadmium 115. The scheme of disintegration of cadmium 115 will be discussed.

* Supported by a grant of The Development Fund of the Ohio State University.
[1] J. M. Cork and others. Bull. Am. Phys. Soc. **25**, 47, V10 (1950).

D9. Forbidden Shape Beta Spectrum of Sb^{124}.* L. M. LANGER, R. D. MOFFAT, AND H. C. PRICE, JR., *Indiana University.*—By means of improved techniques and higher specific activity sources, the beta-spectra of $Sb^{124}(60.d)$ have been reinvestigated in greater detail and with greater accuracy than was possible previously.[1] The 40 cm radius of curvature, shaped field spectrometer was used for the measurements. It is now found that the highest energy group has a spectrum shape of different from that of an allowed transition. The observed distribution is satisfactorily explained by means of the factor a, characteristic of a once forbidden transition involving a spin change of two units and a parity change. The twice forbidden factor c does not fit the data. The ft value is $\sim 10^{10}$. According to the nuclear shell model, the transition from $_{51}Sb_{73}^{124}$ to the ground state of $_{52}Te_{72}^{124}$ is expected to have a parity change. Because of the forbidden shape, the end-point values for the two highest energy groups are changed to $2.291\pm.005$ and $1.69\pm.01$ Mev. A gamma-ray corresponding to this energy difference was reported earlier.[1] A search was made for possible positron emission to Sn^{124} and also for Auger electrons following possible K-capture. No indication was found that these processes compete in measurable amounts with the observed negatron emission to Te^{124}.

* Assisted by a grant from the Frederick Gardner Cottrell Fund of the Research Corporation and by the Joint Program of the ONR and AEC.
[1] C. S. Cook and L. M. Langer, Phys. Rev. **73**, 1149 (1948).

D10. Re182 and Re183 by Relative Cross Sections. H. TALMAN DYBVIG AND M. L. POOL, *Ohio State University.*—It has been determined through relative cross-section measurements that a $14H$ activity which decays by K-capture with a 0.92 Mev γ-ray is located in Re182 and a $2.8D$ activity decaying by K-capture with a 1.75 Mev γ-ray is to be found in Re183. In addition, the $3.79D$ activity of Re186 was confirmed. These activities were produced by deuteron bombardments on tungsten in which enriched isotopes from Oak Ridge were used. The enriched isotopes ($W182$ and $W183$) which were received in the oxide state were reduced to the metallic state before bombardment; and after bombardment, the tungsten and rhenium fractions were chemically separated. The relative cross-section calculations which give the above results were made using the $3.79D$ activity of Re186 and the $24.1H$ activity of $W187$ as monitors.

D11. Radiations from Os^{185}, Os^{191} and Os^{193}.* MERLE E. BUNKER, ROBERT CANADA, AND ALLAN C. G. MITCHELL, *Indiana University.*—The radiations from Os^{185} (97 days), Os^{191} (32 hr.) and Os^{193} (15 days) have been investigated with the help of a magnetic lens spectrometer. Os^{185} decays by orbital electron capture accompanied by two gamma-rays of energy 0.648 and 0.878 Mev. The number of gamma-ray quanta of 0.648 Mev is six times that of 0.878 Mev. Os^{191} decays by the emission of beta-rays of maximum energy 1.10 Mev and does not appear to be accompanied by any gamma-rays. Os^{185} decays by beta-particle emission accompanied by two gamma-rays of energy 0.128 Mev and 0.041 Mev. The beta-ray spectrum is obscured by internal conversion and Auger lines. The end point is approximately 0.135 Mev.

* Assisted by the joint program of ONR and AEC.

D12. Los Espectros Continuous de los β-Rayos de los Gases Radioactivos en la Cámara de C. T. R. Wilson. MARGUERITE M. ROGERS* Y F. T. ROGERS, JR.,* *University of North Carolina.*—Los espectros de los β-rayos, por ejemplo de[1] Hídrogeno 3 y[2] Bismuto 210, han sido deducidos por las medidas de la distribución, $H(p)$, de las proyecciónes de las trayectorias (por H^1H^3O y $Bi^{210}(CH_3)$ respectivamente) en una cámara de Wilson. Permitimos $H(p)=\Sigma a_i \exp(-b_i p^2)$ ó $\Sigma c_{2i} p^{2i}$; pues la relación

$$H(p)\sim\int_x\int_\phi G(p\csc\phi)dxd\phi$$

de la distribución, $G(l)$, de las longitudes; aquí $\mathbf{x}$ es el eje de observación y ϕ es el ángulo con $\mathbf{x}$. Desués de corrección de la estadística por las longitudes y los torcimientos, la distribución de las energías cinéticas se obtienen esencialmente por multiplicación con la raíz cuadrada del alcance. Este método, primeramente intendado por A. Leigh-Smith y H. O. W. Richardson, parece superior en ciertas investigaciónes con el espesor minimo del soporte por la materiál radioactiva.

* Ahora en U. S. Naval Ordnance Test Station, Inyokern, California.
[1] W. J. Byatt, F. T. Rogers, Jr., y A. W. Waltner, Phys. Rev. **75**, 909 (1949).
[2] A. W. Waltner y F. T. Rogers, Jr., Phys. Rev. **75**, 1445 (1949).

THURSDAY MORNING AT 10:00

Anfiteatro Bolívar

(I. I. RABI presiding)

Symposium on Cosmic Rays

E1. Geomagnetic Analysis of the Primary Spectrum. MANUEL SANDOVAL VALLARTA, *El Colegio Nacional y Instituto de Física. Universidad de Mexico.* (20 min.)

E2. Geomagnetic Effects at the Top of the Atmosphere. J. R. WINCKLER, *University of Minnesota.* (20 min.)

E3. The Magnetic Field of the Sun. D. H. MENZEL, *Harvard University.* (20 min.)

E4. The Energies and Nuclear Interactions of Heavy Primary Rays. E. P. NEY, *University of Minnesota.* (20 min.)

E5. On the Nature of the Primary Cosmic Rays. H. L. BRADT, *University of Rochester.* (20 min.)

E6. Disintegrations and Meson Production by Relativistic Particles at Different Latitudes. E. O. SALANT, *Brookhaven National Laboratory.* (20 min.)

THURSDAY AFTERNOON AT 15:00

Anfiteatro Bolívar

(C. C. LAURITSEN presiding)

Symposium on Cosmic Rays, Concluded

F1. Nuclear Collisions Between High Energy Cosmic-Ray Particles. MARCEL SCHEIN, *University of Chicago.* (20 min.)

F2. The Abundance and Masses of Cosmic-Ray Particles at Low Elevations. R. B. BRODE, *University of California, Berkeley.* (20 min.)

F3. The Particles in Penetrating Showers. C. D. ANDERSON, *California Institute of Technology.* (20 min.)

F4. Penetrating Showers from Carbon and Lithium. W. B. FRETTER, *University of California, Berkeley.* (20 min.)

F5. Neutrons in the Cosmic Rays. S. A. KORFF, *New York University.* (20 min.)

F6. Some Properties of the New Unstable Cosmic-Ray Particles. R. B. LEIGHTON, *California Institute of Technology.* (20 min.)

THURSDAY AFTERNOON AT 15:00

Minería

(E. S. AKELEY presiding)

Invited Paper

G1. Theories of Gravitation. H. P. ROBERTSON, *California Institute of Technology.* (40 min.)

G2. A Perfectly Symmetrical Universe in Flat Space-Time. CARLOS GRAEF FERNÁNDEZ, *Institute of Physics of the University of Mexico.* (20 min.) (Absrtact underneath.)

Gravitation, Relativity, Theoretical Physics

G2. A Perfectly Symmetrical Universe in Flat Space-Time. CARLOS GRAEF FERNÁNDEZ, *Institute of Physics of the National University of Mexico.* (Introduced by M. S. Vallarta).—A cosmology is developed in the flat space-time of Einstein's theory of special relativity as an extension of Birkhoff's theory of gravitation to cosmical scale. It is assumed that the metagalaxy is perfectly symmetrical; i.e., that the mass-density measured at all galaxies is the same function of the age of the universe. A consequence of this type of symmetry is a universe with a finite volume and an infinite mass. The distribution function for the velocities of the galaxies is obtained, and so is the total number of galaxies for a given apparent magnitude.

G3. Potentials of a Rotating Spherical Shell in Birkhoff's Theory of Gravitation. FERNANDO ALBA, *Institute of Physics of the National University of Mexico.*—Starting with the potentials of Birkhoff's theory due to a moving particle, the gravitational potentials of a rotating spherical shell are obtained for the interior and for the exterior of the sphere. These potentials can be expressed exclusively in terms of zonal harmonics of the orders zero and two. The equations of

motion of a particle moving in the interior or in the exterior of the spherical shell are established. The exterior potentials for a rotating sphere can be easily obtained if the density is a function of the radius alone.

G4. Vector Boundary Value Problems and Their Applications. J. ADEM AND M. MOSHINSKY, *Institutos de Geofísica y Física, Universidad de México.*—Some problems in the field of heat conduction and in vibration phenomena have suggested the formulation of a special type of boundary value problem. For example, the problem of heat conduction in a cross, is a complex one when one considers the surface of the same as a boundary. If, on the other hand, we define the vector $\theta=(\theta_1, \theta_2, \theta_3, \theta_4)$ in which each of the components $\theta_i(x, t)$ correspond to the temperature associated with a corresponding branch of the cross, the problem reduces to that of conduction of heat in 4 bars with appropriate boundary conditions at the end points, and it can be completely solved. We have discussed the general mathematical formulation of these problems, in which the vector function satisfies both, a matrix differential equation in the interval $[0, 1]$ and general boundary conditions at the boundary of the interval. The method has been applied to the conduction of heat in interconnected rings, in a reel, in a wheel, etc., and to problems of vibrations of plates that interact through an elastic medium, etc. The methods developed suggest interesting analogies for some nuclear physics problems.

G5. Un Cero de una Cierta Función de las Funciónes de Bessel. F. T. ROGERS, JR., *U. S. Naval Ordnance Test Station,* Y H. L. MORRISON, *North Carolina State College of Engineering.*—Permitimos $\nu(R)=+(1+1/R^2)^{\frac{1}{2}}$, $u(R, r, \rho)=+(1/rR-\rho/R^2)^{\frac{1}{2}}$, y $c=\exp(-\pi R)$. El cero primero de $J_\nu(u)J_{-\nu}(cu)-J_\nu(cu)J_{-\nu}(u)$ con respecto á $\rho<0$, por $R>0$ y $r>0$, se requiere[1] en problemas ciertas de la estabilidad critica dinámica de los fluidos. Este cero se identifica por los ν-valores positivos de los enteros medios nones, de $\rho=R/r-M(R)$. Hemos computado de un método numérico que $M(R)=2.25+7.17R+10.71R^3$ por $0\leq R\leq 0.9$; estimamos en $M(R)$ incertidumbres menor de 0.05 de la desviación promedia.

[1] Esto determina, por ejemplo, la cercanía térmica circa de la estabilidad critica en el fluido real (en otras palabras, con un coeficiente $\neq 0$ por la dilatación termal) que es impidiendo según la ley de Darcy.

THURSDAY AFTERNOON AT 15:00

Minería

(L. MARTON presiding)

Mostly Electron Physics and Optical Physics

H1. Effect of Space Charge on Pulsed Electron Beams. SURINDRA N. KALRA, AND WILLIAM J. FRY, *University of Illinois.*—The effects of space charge on the definition of pulsed electron beams is investigated. Three types of pulses are considered, namely, plane parallel pulses of infinite extent, coaxial cylindrical pulses of infinite length, and concentric spherical pulses. By considering the expansion of surfaces of the same geometry as the pulses, the expansion of the set of pulses due to space charge forces alone can be studied. A uniform initial charge density inside each pulse is assumed. In case of a single pulse of any of the three geometrics described above, the time, τ, needed for the pulse to double its initial dimensions is independent of the initial dimensions. The current density, J, such that in time, τ, the pulses just double themselves in dimensions for zero initial velocity is given by: $J_0=5.96\times10^{-17}\phi^{\frac{1}{2}}/\tau^2$ for plane parallel pulses, $J_\tau=4.64\times10^{-17}\phi^{\frac{1}{2}}/\tau^2$ for spherical, and $J_0=1.37\times10^{-16}\phi^{\frac{1}{2}}/\tau^2$ for cylindrical pulse; where ϕ is the beam potential in m.k.s. units. It can be shown that during the expansion of the pulses under space charge forces the separation between successive infinite plane parallel pulses remains constant and the charge density at any time is uniform insider every pulse, and τ is the same for all pulses. In the cases of spherical and cylindrical pulses, successive pulses catch up with one another.

H2. Generation of Coherent Electromagnetic Radiation. LLOYD T. DEVORE, SURINDRA N. KALRA, AND WILLIAM J. FRY, *University of Illinois.*—Possible limitations on the generation of coherent e.m. radiation are considered with respect to a coupling system fed by a pulsed electron beam. After a certain length of time, an equilibrium is reached in the coupling and radiating device such that the energy radiated plus that lost because of resistance of the walls, etc., in a unit time is equal to the energy input. At equilibrium, the product of energy and frequency in the coupling device is $P=(QJ^2A^2l^2)/(\pi f\epsilon V)$, where J is the current density, A the area and l the length of the path of the current beam through the device, f the frequency, ϵ the permitivity and V the volume. If the volume of the device is large compared to one wave-length, then the noise power is given by $P_n=(8\pi kTVf^4)/(QC^2)$. If γ is the signal to noise ratio required, then $P=\gamma P_n$ yields the minimum value of Q needed at any frequency or for a given value of Q, it yields the maximum frequency that can be generated with a given value of γ. For spherical metal cavities, this relation reduces to $f^6=1.97\times10^{73}J^2/\gamma$. The limitations on J are discussed in the preceding paper.

H3. Space Charge Distribution in a D.C. Cut-Off Magnetron. D. REVERDIN AND L. MARTON, *National Bureau of Standards.*—The elementary magnetron was investigated by sending an electron beam axially through the tube. From the complicated shadow patterns cast by two wire screens, one can determine the change of direction of individual trajectories of the exploring beam due to the electric space charge field in the magnetron. The conclusions of the study are that the space charge distribution does not conform to Hull's predictions. Three different shapes of space charge distribution were observed. One has a sharp maximum near the cloud radius. The second falls off gradually toward the cathode. The third is time variant. The shape of the space charge distribution is closely related to the symmetry of the magnetron. The experiments seem to confirm Haeff's theory of noise amplification in a dense space charge cloud. The presence of a double stream of electrons is very probable.

H4. Electrostatic Charging of Aircraft Glass During Flight. E. STICKLEY, *Pittsburgh Plate Glass Company,* M. M. NEWMAN AND J. D. ROBB, *Lightning and Transients Research Institute.*—Loss of radio communication occurs when flying through serious precipitation static conditions. The role of the glass portions of the aircraft surface in this phenomenon has been investigated. It has been established that streamering

discharge across the glass surface, as a result of triboelectrification, is a major cause of radio interference. The resultant electrical transients and their interaction on radio receiving equipment were recorded by high speed oscillography. In contrast to earlier corona oscillograms which were distorted and lengthened by amplifier time constants, the steep impulsive nature of streamer and corona transients was brought out by new wide-band amplifier techniques.

H5. General Theory of Voltage Stabilizers. J. J. GILVARRY AND D. F. RUTLAND, *Rand Corporation and Institute for Numerical Analysis, N. B. S.*—The standard theory of voltage stabilizers,[1] which characterizes a stabilizer by three parameters (the stabilization ratio, internal resistance, and equivalent bleeder conductance), requires an approximation in general application, since an active four-terminal network requires four parameters for its specification. A fourth parameter can be obtained by a generalization of the equivalent bleeder conductance to yield two parameters. Defining the four-performance parameters as independent of load, one can construct an equivalent circuit of four elements (which are functions of the performance parameters) for the general voltage stabilizer. The general solution of the problem of expressing the over-all performance parameters of a stabilizer in terms of parameters of the stabilizer itself and the load and supply resistances then follows directly. As compared to previous results[1] (which now refer strictly to an identifiable special case only), no change in the general formula for the over-all stabilization ratio S occurs, but the formula for the over-all internal resistance R requires a correction. Confirmatory experimental results will be presented.

[1] F. V. Hunt and R. W. Hickman, Rev. Sci. Inst. **10**, 6 (1939).

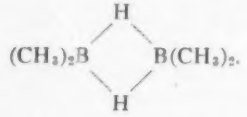
H6. Gyroscopic Stabilization of a Free Body.* J. K. TYSON, *Armour Research Foundation.*—The orientation of a free body may be stabilized by the use of three gyroscopes pointing in mutually perpendicular directions only if the gyroscopes are free to precess about mutually perpendicular axes. The equations of motion of the system are the Lagrange-Euler equations, which may be extended to bodies having internal degrees of freedom, and three equations for the precession of the internal gyroscopes. Solution of the linearized equations for the system demonstrates the approximate stability of the orientation against small torque impulses, while an approximate solution of the non-linear equations provides a description of the behavior under torques of long duration. The initial motion of the body is a uniform rotation at a rate governed by the frictional torques resisting precession of the gyros, while approximate stabilization is maintained for a torque impulse equal to the total angular momentum change of the gyros during their precession.

* Work sponsored by Equipment Laboratory, Air Materiel Command.

H7. Mass Spectrometric Studies of Two Series of Organic Compounds.* ANTHONY DONFOR, WEBSTER KENDRICK, AND HERMAN BRANSON, *Howard University.*—The two series (1) methane, methyl chloride, dichloromethane, chloroform and carbon tetrachloride, and (2) methyl amine, dimethyl amine, and trimethyl amine have been studied in a 60° Nier-type mass spectrometer. The electron intensity was 50 volts. Appearance potentials have been obtained for the molecular fragments. The data are viewed as additional information on the forces operating in the molecules.

* Assisted by the ONR and Research Corporation of New York.

H8. Raman Spectra at Low Temperatures. The Raman Spectrum of Tetramethyl Diborane. BERNARD RICE, J. M. GONZALEZ-BARREDO, AND T. F. YOUNG, *University of Chicago.*—Apparatus for the production of the Raman spectrum of a substance at a low temperature and in the absence of air has been designed and constructed. The Raman tube is encased in the upper part of a drilled copper rod the lower end of which is immersed in a Dewar flask containing a coolant, e.g., liquid nitrogen. Windows in the copper jacket admit the exciting light. The Raman spectrum of liquid tetramethyl diborane at a temperature below 0°C was photographed. The lines observed included none with frequencies characteristic of terminal boron-hydrogen stretching. This fact is evidence for a hydrogen-bridge structure in the tetramethyl diborane molecule:



It also constitutes further evidence for a bridge structure in diborane. In the frequency range characteristic of bridge-hydrogen stretching two lines exist, instead of the one strong one found in the spectrum of diborane, B_2H_6.

H9. The Detection of Soft X-Rays with a Scintillation Counter.* LYMAN A. WEBB, RONALD S. PAUL, AND FRANCIS E. DART, *University of Oregon.*—Using a tube having a pure tungsten filament and an aluminum anode, x-rays in the range 5.6A to 15.5A (800 to 2200 ev) have been detected with a scintillation counter. The phosphor screen of wurtzite or other material protected from light by films of plastic and aluminum about 0.0002 cm thick is exposed to the x-rays within the tube. Scintillations are detected by an IP21 photo-multiplier tube and the signals passed through a linear amplifier and pulse height discriminator before they are counted with a conventional scaler. It is assured by means of grids placed in front of the screen that the scintillations observed cannot be due to electrons or ions. Counting rates are measured successively at various discriminator levels, the discriminator level being raised by 5 percent of the maximum pulse height at each successive measurement. The integral bias curves thus obtained are used to plot differential pulse height curves. These are able to detect the Al K line at 8.32A. Data will be presented on the effect of protecting film thickness on the wave-length threshold for detection of x-rays, on the results obtained with different phosphors, and on results obtained with different target materials in place of aluminum.

* Research supported in part by Geophysical Research Directorate, Air Force Cambridge Research Laboratories.

H10. Scintillation Properties of Solutions.* G. T. REYNOLDS AND F. B. HARRISON, *Princeton University.*—Experiments reported previously[1] have been extended to include a systematic study of many solutions, the effect of concentration of the solution, and the emission spectra of various solutions. Results show that terphenyl in *m*-xylene, *p*-xylene, or thiophene-free benzene give pulses about 0.4 the height of anthracene crystal pulses when observed with a 5819 photo-multiplier. Other solutions will be compared. A noticeable scintillation effect is observed with as little as 3 parts by weight of terphenyl in 100,000 parts of solvent. The response of various solutions to the cesium 600-kilovolt electron will be shown and compared to the response of an anthracene crystal. The emission spectra of solutions irradiated with ultraviolet light or x-rays contain significantly shorter wave-lengths than the corresponding spectra of crystals. The spectra of terphenyl and anthracene will be discussed in detail, as will the problem of matching the various scintillators with appropriate photomultipliers.

* This work was supported by the joint program of the ONR and AEC.
[1] Reynolds, Harrison, and Salvini, Phys. Rev. **78**, 488 (1950).

H11. Probability of Auto-Ionization in Light Atoms. TA-YOU WU AND L. OUROM, *National Research Council, Canada.*—With the view of testing the adequacy of the method of treat-

ing such problems, the probability of radiationless transition of the $1s^22p3s\ ^3P$ state of Be to the continuum $1s^22s$+ejected p electron has been calculated according to the usual perturbation theory. The discrete wave functions are obtained by the variational method and the continuous wave function is obtained by numerical integration of the Schrodinger equation. The transition probability so obtained is $\sim 5\times 10^{13}$ per second, leading to a width of ~ 250 cm^{-1} for the level $1s^22p3s\ ^3P$. This is at least 10^3 times larger than what is indicated by the widths of the spectral lines observed. This result, together with similar earlier calculations for the He atom, shows that the perturbation theory is inadequate for the light atoms. It is also pointed out that in these calculations and those on the Auger effect in the literature, there is an inconsistency in the use of the perturbation, since the use of variational or "screened" wave functions implies that a part of the electron-electron interaction has already been included in the initial approximation and it is hence incorrect to treat this whole interaction as the perturbation causing the transition.

H12. Isotope Shift in the C^{14} Atomic Spectrum for $2p^1S_0 - 3s^1P_0$.* JOHN R. HOLMES, *University of Southern California.*—A measurement has been made of the wave number difference between the above line of C^{12} and that of C^{14} in order to compare it with the previous measurement of isotope shift in C^{13}.[1] It was thought that because of some change in nuclear structure there might be an anomalous shift in the spectrum of C^{14} such that the splitting between the lines of C^{12}, C^{13}, and C^{14} would not be due solely to the change in nuclear mass. The change in the Rydberg constant between C^{12} and C^{14}, the normal mass effect, would predict an isotope shift in this line of plus 0.261 cm^{-1}. The experimental measurement gave a shift of minus 0.294 cm^{-1}, indicating a "specific mass effect"[2] of minus 0.555 cm^{-1}. Comparing this with C^{12},[1] there seems to be no anomaly since the observed shifts are proportional to the percentage change in mass. This is the result expected from any effect depending solely on a change in nuclear mass, as contrasted with the nuclear volume effects found in heavy elements.[3]

* Supported by ONR.
[1] John R. Holmes, Phys. Rev. **77**, 745 (1950).
[2] D. S. Hughes and Carl Eckart, Phys. Rev. **36**, 694 (1930).
[3] M. F. Crawford and A. L. Schawlow, Phys. Rev. **76**, 1310 (1949).

H13. A New Mounting for an Echelette Diffraction Grating. W. F. C. FERGUSON AND J. H. GREIG, *New York University, Washington Square.*—With this mounting a single ruled echelette grating may be used "in the blaze" over a very wide range of wave-lengths. This is accomplished by tilting the grating with respect to the incident light as in a Littrow mounting, and then rotating the grating about an axis perpendicular both to the grating elements and the incident beam. By this rotation the path difference between beams of light reflected from successive elements of the grating may be varied from a maximum value, the ordinary blaze wavelength, to zero. The spectrum reflected from the grating may then be reflected from a plane mirror, rotating with the grating, to produce a constant deviation mounting. The image of the slit is found to be tilted as the grating rotates. This can be compensated by a rotation of the slit. In a trial, using an echelette designed for the near infra-red, all orders of the sodium D-lines from the fifth to the first were caused to pass an observing telescope, successively in the blaze, by a 55 degree rotation of the grating mounting.

THURSDAY EVENING AT 21:00

Anfiteatro Bolívar

(MANUEL SANDOVAL VALLARTA presiding)

El sol y el universo. D. H. MENZEL, *Harvard University.*

(Conferencia popular ilustrada con la espectacular película "Explosiones en el Sol," que muestra gráficamente las protuberaciones gaseosas en la atmósfera solar)

FRIDAY MORNING AT 10:00

Anfiteatro Bolívar

(I. I. RABI presiding)

Invited Papers

I1. Electrostatic Direct-Current Transformer of 300 Kilovolts. JOSE MIRELES MALPICA, *Instituto Politecnico.* (15 min.) (Abstract printed under D1).

I2. Evolution of Modern Physics. R. A. MILLIKAN, *California Institute of Technology.* (40 min.)

I3. Low Velocity Layers in the Earth's Interior, the Ocean and the Atmosphere. BENNO GUTENBERG, *California Institute of Technology.* (40 min.)

I4. Lattice Imperfections and Plastic Flow in Metals. FREDERICK SEITZ, *University of Illinois.* (30 min.)

FRIDAY MORNING AT 10:00

Minería

(C. C. LAURITSEN presiding)

Gamma-Rays and Neutrons

J1. Gamma-Neutron Cross Section of Some Isotopes for γ-Ray Energies up to 27 Mev. L. KATZ, H. E. JOHNS, R. A. DOUGLAS, AND R. N. H. HASLAM, *University of Saskatchewan.*—Using the Schiff formula for bremsstrahlung in the forward direction[1] from a thin target and the computed response of an "r" meter to high energy γ-rays, it has been possible to calculate (γ, n) cross sections from the yield curves of these reactions induced by γ-rays from a betatron. We find the $Cu^{63}(\gamma, n)Cu^{62}$ cross section to have its maximum at 17.5 Mev and a value of 0.10 barn. The curve is fairly symmetric about this energy having a half width of 6 Mev and area of 0.6 Mev-barn between 11 and 24 Mev. This width is very much greater and is centered around a lower energy than that reported by Baldwin and Klaiber.[2] Our absolute value for the cross section is in good agreement with that obtained using Li γ-rays. The values for other reactions examined were

$Cu^{63}(\gamma,n)^{64}$	19 Mev	0.02 Barn	6 Mev	0.12 Mev barn
$Sb^{121}(\gamma,n)Sb^{120}$	14.5	0.20	6	1.2
$Sb^{123}(\gamma,n)Sb^{122}$	14.5	0.28	6	1.5
$Ta^{181}(\gamma,n)Ta^{180}$	13.5	0.05	5	0.26

[1] H. W. Koch and R. E. Carter, Phys. Rev. **77**, 165 (1950).
[2] G. C. Baldwin and G. S. Klaiber, Phys. Rev. **73**, 1156 (1948).

J2. Gamma-Rays Induced by the Proton Bombardment of Phosphorus.* G. RICHARD GROVE,† JOHN N. COOPER, AND J. C. HARRIS, *Ohio State University.*—Phosphorus has been bombarded by protons from the Ohio State Van de Graaff generator and a number of narrow (p, γ) resonances observed. The gamma-ray yield as a function of generator voltage reveals distinct intensity maxima at approximately 1.08, 1.11, 1.14, 1.17*, 1.27*, 1.43*, 1.47*, 1.50, 1.54, 1.59*, and 1.62* Mev, where the asterisks indicate the more intense peaks. The energies of the protons were obtained from the analyzing magnet current, which was calibrated in terms of the fluorine resonances. The cross sections for all these resonances are low; for the most intense, that at 1.27 Mev, the cross section is estimated to be of the order of 0.0004 barn by comparison with the fluorine 340 kev resonance. Thick and thin targets of zinc phosphide, evaporated on nickel and tantalum, have been studied. The thinnest target had a thickness of roughly 10 kev at 1.3 Mev.

* Assisted by the joint program of the ONR and the AEC.
† AEC Predoctoral Fellow.

J3. Gamma-Resonances in Magnesium Bombarded with Protons.* JOHN N. COOPER, WARREN E. TAYLOR, J. C. HARRIS, AND G. RICHARD GROVE.† *Ohio State University.*—Protons from the recently completed Ohio State University Van de Graaff generator have been used to bombard thin magnesium targets, prepared by evaporation on tantalum in a vacuum. A large number of gamma-resonances are observed in the voltage region between 0.35 and 1.5 Mev. In the vicinities of 450 and 720 kev there is considerable activity over a broad region; this activity has not yet been resolved. At proton energies of about 0.88, 1.03, 1.06, 1.11, 1.22, 1.26, and 1.35 Mev very distinct resonance yields of gamma-rays are observed. Near the 1.03 Mev resonance there is good evidence for the presence of two incompletely resolved "satellites." The contours of several other resonances suggest that they are not due to single levels. The complex nature of gamma-ray yield as a function of proton energy is not surprising in view of the fact that all three stable isotopes of magnesium were present in the targets.

* Assisted by the Joint Program of the ONR and the AEC and by the Ohio State University Development Fund.
† AEC Predoctoral Fellow.

J4. Measurement of Gamma-Ray Energies With Crystals of NaI(Tl). R. HOFSTADTER AND J. A. MCINTYRE, *Princeton University.*—A monoenergetic gamma ray (Energy $E_0 > 2mc^2$), on impact with a crystal of NaI(Tl) produces three pulse distributions according to the three possible interactions (a) Compton effect, (b) Photoelectric effect, (c) Pair production. The Compton effect results in a wide distribution of recoil electron energies, while the latter two interactions produce very narrow electron energy distributions. The photoelectric "line" has the energy $E_0 - E_K$ and the pair "line" $E_0 - 1.02$ Mev where E_K is the binding energy of the K electron in iodine. We have succeeded in observing all three distributions simultaneously in the same crystal. A single gamma-ray line therefore produces three peaked distributions two of which are sharp lines. Because of this multiplicity, careful consideration must be given to assignments in a complex gamma-spectrum. The two crystal coincidence spectrometer previously described[1] eliminates the photoelectric line but leaves the pair line along with the desired Compton peak. The pair line arises because an annihilation quantum is captured in the gate detector crystal. Results with Na^{24}, Co^{60}, Sb^{124} will be shown. This work was supported by the U. S. Army Signal Corps and by the joint program of the ONR and AEC.

[1] Bull. Am. Phys. Soc., Washington Meeting, 1950, paper G2.

J5. Angular Distribution of Gamma-Rays from Fluorine. R. B. DAY, C. Y. CHAO, W. A. FOWLER, AND J. E. PERRY, JR., *California Institute of Technology.*—Investigations are being made of the angular distribution of the γ-rays from the reaction $F^{19}(p, \alpha\gamma)O^{16}$. The detecting apparatus, which is similar to that used by Devons and Hine,[1] consists of Geiger counters mounted on a frame work that can be rotated about the target chamber. Coincidences between the front and back counters are recorded and provision is made for varying thicknesses of aluminum absorber to be placed between the counters. The target chamber and detecting equipment are surrounded by a large housing of lead bricks to reduce background radiation. Preliminary results indicate that the distribution is of the form $1 + a\cos^2\theta$. The values of a at various resonances are tabulated below.

E_p (kev)	873	935	1290	1355	1381
a	0.14	0.02	0.69	0.30	−0.03

This work was assisted by the joint program of the ONR and AEC.

[1] Devons and Hine, Proc. Roy. Soc. **199A**, 56 (1949).

J6. Neutron Capture Gamma-Ray Spectra. BERNARD HAMERMESH, *Argonne National Laboratory.*—The D_2O-soaked plate technique[1] has been applied to the neutron capture γ-ray[2] spectra of Al, Cl, Fe, Br, Cd, La, W, Au, and Hg. The method is limited to energies above 3 Mev and the energy resolution is approximately ±0.25 Mev. The spectra may be classified as follows: 1) Cd and Hg. The intensity is probably still rising below 3 Mev. The intensity decreases steadily up

to the high energy cut-off of the spectrum. There is no evidence of line structure. 2) Fe, Br, La, and W. The intensity is a maximum near 5 Mev. There is evidence of line structure. 3) Al, Cl and Au. The intensity is nearly constant over a wide range of energies. There is evidence of line structure. The spectra of the heavy elements W, Au and Hg might be expected to be similar on the basis of a statistical nuclear model. It is suggested that the differences may be due to the different odd-even character of the compound nuclei that probably emit the γ-rays, i.e., W^{187}, Au^{198}, and Hg^{200}.

[1] G. Goldhaber, Phys. Rev. **74**, 1725 (1948).
[2] B. Hamermesh, Phys. Rev. **76**, 182 (1949).

J7. Polarization Effects of Scattered Neutrons. W. E. MEYERHOF, D. B. NICODEMUS, AND FELIX BLOCH, *Stanford University.*—When a neutron is scattered from a nucleus ($I \neq 0$) there exists a finite probability Q of spin flip of the neutron, which permits a calculation of the spin scattering lengths.[1] We are measuring the spin flip probability by the change in polarization of a polarized beam of slow neutrons due to single scattering from various substances. Two ½ in. thick iron blocks magnetized to saturation are used as polarizer for the neutron beam and analyzer for the scattered neutrons respectively. The cyclotron producing the neutrons is pulsed to reduce the fast neutron background. The experiment is complicated by the smallness of the singly scattered neutron intensity (20–50 slow neutrons/min.). To check the method we have measured Q for carbon ($I=0$) and found $Q=0.15\pm0.25$, the expected value being $Q=0$. Other results will be presented.

[1] O. Halpern and M. H. Johnson, Phys. Rev. **55**, 898 (1939).

J8. Variation of High Energy Neutron Collision Cross Sections with Energy. J. DEJUREN AND B. J. MOYER, *University of California, Berkeley.*—An investigation of the variation of nuclear total cross sections for neutrons between 90 and 270 Mev has been made using bismuth fission for detection. The bombardment of a 0.5 in. Be target with protons in the 184 in. cyclotron produces a neutron flux of mean energy approximately 70 Mev less than the incident proton energy for bombarding energies between 160 and 350 Mev. The total cross sections of carbon, aluminum, copper, and lead approach constant values in the neutron energy interval between 180 and 270 Mev. The total hydrogen cross section decreases less rapidly than $1/E$. At 95, 160, 220, and 270 Mev, its values are respectively 73 ± 1.5, 51 ± 2.6, 41 ± 2.4, and 38 ± 1.5 millibarns.

J9. Experiments Upon Anisotropic and Inelastic Scattering with a Highly Collimated Neutron Beam. ALEXANDER LANGSDORF, JR., *Argonne National Laboratory.*—Neutrons are collimated by a tapered hole on the axis of a truncated conical shield whose apex is located at the source, the target of an electrostatic generator. The usual detector consists of nine BF_3 proportional counters on each of seven circles at increasing radii. The counters are embedded in a paraffin ring (17 in. O.D., 2¾ in. I.D., 13 in. long) 50 in. from the target and inside a cylindrical shield in back of the cone. The beam (of 10^{-3} steradian) only reaches the ring detector when scattered by a sample. Anisotropic scattering is measured by locating the scatterer before, in, or beyond the ring. For one Mev neutrons, and isotropic scattering, over-all efficiency of counting reaches 20 percent at the central position, and backgrounds are about 10 percent for scatterers of 90 percent transmission. Shielding is still adequate up to at least 1.5 Mev. Anisotropy associated with resonance scattering is particularly interesting. An "age" distribution is obtained from the radial counting distribution; once calibrated this gives information on neutron energy and hence inelastic scattering. Anisotropy effects complicate interpretation. These techniques give low resolution data very rapidly. Higher resolution may be obtained using the same equipment in other ways with lower counting rates. Transmission cross section data is readily obtained with small samples.

FRIDAY MORNING AT 10:00

Minería

(R. B. BRODE presiding)

Cosmic Rays, I

K1. Camaras para Rayos Cosmicos. R. RICHARD-FOY, *Comision Impulsora de la Investigacion Cientifica, Mexico.*—Construímos seis cámaras chicas de Wilson trabajando en paralelo con propósito de medir la variación de ionisación a través de placas de plomo puestas entre cámaras. La expansión esta regulada automáticamente en función de la temperatura por un dispositivo de control de la presión detrás del pistón. Las cámaras quedan así ajustadas mas de una semana y se modifican solamente por la evaporación de la humedad. Tres grupos de dos contadores puestos en coïncidencia, y un grupo de cuatro en anticoïncidencia seleccionan las particulas que se paran. El dispositivo electrónico de seleccion tiene solamente cuatro tubos y un thyratron, y funcionó satisfactoriamente durante un año. Las fotografías se sacan por dos cameras cuyos obturadores estan syncronisados con la luz, lo que permite observar al mismo tiempo que se fotografía. Tenemos 20 cm de profundidad de campo a 80 cm de distancia con apertura $f/16$ y una dirección de toma a 25° del haz luminoso El consumo total, incluyendo producción de aire comprimido es menor de 500 w siendo así possible trabajar en altura. Las experiencias siguen y daremos oportúnamente informe de los resultados.

K2. A Proportional Counter Technique. LEO R. DAVIS, C. W. KISSINGER, AND G. J. PERLOW, *U. S. Naval Research Laboratory.*—A method has been devised for making simultaneous range and ionization measurements on charged cosmic rays by use of a proportional counter and Geiger counters. The latter form a telescope defining a beam through the former. The proportional counter pulse is registered only when the Geiger tube telescope furnishes an appropriate trigger. To investigate the fluctuations in the ionization determination, an experiment was performed using as test particles the sea-level mesons capable of penetrating 10 cm Pb. The distribution curve (number *versus* pulse height) obtained was relatively broad. The effect of geometrical variation in path length through the proportional counter has been shown to be unimportant. The fluctuation due to the statistics of the multiplication process was worked out by analogy with the Furry model of a cascade shower. This also accounts for a

small fraction of the observed width of the curve. Finally, the theory of Landau on the fluctuation of the energy loss in the gas, coupled with the wide spread in energy of the mesons, fits the observed data reasonably well. Mesons of very high energy contribute significantly to the width through the logarithmic increase of ionization with speed.

K3. Rocket Measurement of Cosmic-Ray Ionization and Range. G. J. PERLOW, T. A. BERGSTRALH, C. Y. JOHNSON, AND J. D. SHIPMAN, JR., *U. S. Naval Research Laboratory.*—A V-2 rocket was launched in February at White Sands, New Mexico with a counter telescope containing two proportional counters in a threefold set of Geiger tubes. Below this were absorbers of ~1, 3 and 11 cm Pb. Counter trays below each absorber interrogated as to range and showers each particle accepted by the threefold set. Simultaneously each proportional counter was sampled. The system was calibrated with mesons on the ground. As in previous flights, the soft component above the atmosphere was detected. Almost all of the particles which stop in 1 cm Pb are unequivocally identified as electrons. The larger part of those which penetrate 4 cm but produce no count below 15 cm are also electrons including possibly some primaries. Of the particles which penetrate all the lead the larger number have the properties of primary protons. An alpha-particle group also appears. The best values of the intensities will be presented. Some possible ambiguity in these figures remains due to the bursts always found in rocket experiments.

K4. On the Albedo of Cosmic Radiation.* A. ROMERO JUÁREZ, J. DE OYARZÁBAL, C. GÓMEZ, AND F. MEDINA, *Instituto de Física, Universidad de México.*—The equations of motion of a charged secondary particle in the earth's magnetic field are solved by numerical integration. The secondary particle is produced by impact of a primary at some point of the earth's atmosphere and arrives at some other point. Both dipole and quadripole terms of the earth's field are taken into account, because the secondary particle is never more than an earth's radius away from the earth's surface. Preliminary numerical integrations show that—particles of energy 0.3 Störmer arriving at geomagnetic latitude 40° and geographic longitude 120°W, in the direction given by zenith-angle 60° and azimuth 0° (north) depart from points located very far away in latitude and longitude. The work is being continued for other energies, latitudes and directions of arrival.

* Work done under the auspices of C.I.C.I.C.

K5. On the Primary Cosmic-Ray Spectrum.* J. A. VAN ALLEN AND S. F. SINGER, *Applied Physics Laboratory, Johns Hopkins University.*—Based on recent rocket flights and further analysis, improved experimental values of the vertical intensity of cosmic rays *above* the atmosphere at geomagnetic latitudes 0°, 41°, 50°, and 58° will be presented. The intensities obtained in the range of magnetic rigidities from 2.6 to 15 Bev: (i) are markedly higher than the intensities deduced from ionization integrals, and (ii) follow a considerably flatter spectrum than hitherto believed. Data on the zenith angle dependence of intensity at various latitudes and on the east-west asymmetry at the equator make possible some assessment of the contribution of albedo to the experimental intensities above the atmosphere. However, it still appears that a large fraction of the energy brought in by the primary radiation disappears into forms other than ionization.

* Supported by the Navy Bureau of Ordnance.

K6. The Knee in the Primary Cosmic-Ray Spectrum.* S. F. SINGER AND J. A. VAN ALLEN, *Applied Physics Laboratory, Johns Hopkins University.*—Extending our rocket measurements of the vertical intensity above the atmosphere at $\lambda = 0°$, 41°, 50°, and 58°N by means of the balloon experiment of Pomerantz at 69°, we find a marked flattening of the form of the spectrum for magnetic rigidities below 1.5 Bev ($\lambda = 56°$). The expected diurnal variation calculated in the manner of Dwight, but with the flatter spectrum based on our rocket measurements, turns out to be still very substantial. In the light of recent astrophysical evidence (Thiessen) and absence of an *observed* diurnal variation (Pomerantz, Bergstrahl, Stroud), causes other than the sun's magnetic field should be considered for the existence of a knee: (a) intrinsic scarcity of low energy primary cosmic rays due to the manner of generation and propagation, (b) possible effects of geomagnetic penumbra, resulting in a larger effective cut-off energy at higher latitudes than obtained from the simple Störmer and shadow cones.

* Supported by the Navy Bureau of Ordnance.

K7. The Relative Intensities at 3.4 Kilometers and Sea Level of the Cosmic-Ray Proton Component.* JOSEPH E. HENDERSON, CHARLES E. MILLER, DAVID S. POTTER, AND JAY TODD, JR., *University of Washington.*—Measurements have been made at an altitude of 3.4 kilometers in which magnetic cloud-chamber photographs were taken of those particles stopping in 5 cm of lead absorber. The distribution in momentum of the negatively charged non-shower particles shows a sharp maximum which can be identified as due to negative mesons. The corresponding distribution of positive particles shows two sharp and well-resolved maxima which can be identified as positive mesons and protons. This type of measurement has been repeated at sea level. To date the number of tracks photographed at sea level is statistically inadequate to give accurately the intensity ratio for the two altitudes. Within the present accuracy the meson intensity corresponding to the range 0 to 5 cm lead has decreased by a factor of about 3 and the corresponding proton intensity by a factor of about 10 in going from 3.4 kilometers to seal level. The relative meson intensities are in line with other measurements of the intensity of lower energy mesons, while the relative proton intensities are those to be expected from indirect measurements of the relative intensities at these altitudes of the nuclear cosmic-ray component from studies of star production, slow neutrons and other nuclear phenomena.

* Supported in part by the ONR.

K8. Large Meson Showers Produced by Primary Cosmic-Ray Particles. E. PARKER and B. PETERS, *University of Rochester.*—In photographic emulsions exposed to cosmic radiation one observes occasionally a large number of tracks due to singly charged relativistic particles emanating from a star. These events have usually been interpreted as meson showers. If the plates are exposed at high altitudes (<20 g/cm² of air) one finds that most showers of multiplicity $N \gtrsim 10$ are produced by primary particles of charge $Z > 1$. Of the twelve largest showers observed (ranging in multiplicity from $N = 10$ to $N = 56$) only two ($N = 11$ and 13 respectively) were produced by singly charged particles. Of the remaining 10 large showers five were due to helium nuclei, four to particles of charge $Z = 6$ to 8 and in one case the primary could not be identified. Thus primary particles heavier than helium account for a large fraction of the large showers although they constitute only one percent of the incident radiation. The relative contribution to the large showers made by protons and heavier nuclei depends very critically both on their respective energy spectra and on the way in which multiplicity of meson production depends on the energy of the colliding nucleons. This relation will be discussed.

K9. On the Abundance of Light Nuclei (Li to Si) in the Primary Cosmic Radiation. B. PETERS AND H. L. BRADT, *University of Rochester.*—The determination of the charge Z

of relativistic nuclei has been improved so that up to $Z \sim 12$ to 14 neighboring elements are resolved. In stacks flown at $\lambda = 30°$ geomagnetic latitude below 20 g/cm² air tracks are traced through electron sensitive plates which alternate with strongly underdeveloped insensitive plates, in which grain counting permits a more accurate charge determination than previously obtained. Among the primary nuclei (heavier than hydrogen and helium) carbon, oxygen, nitrogen (?), magnesium, silicon, and neon, roughly in this order, are the most abundant. Most, if not all of the small number of lithium, beryllium and boron nuclei observed must be attributed to high energy fragments resulting from the collision of heavier primary particles with nuclei of the air above the balloon. Since fast nuclei of charge $Z = 3$, 4, or 5 are produced with high probability in nuclear collisions involving fast heavy ions, the absence (or low abundance) of these light nuclei in the primary radiation implies that the heavy nuclei, before hitting the earth, have not traversed an amount of matter sufficient to establish equilibrium with their collision products. Thus if ρ is the average number of atoms per cm³ of interstellar matter along the orbits of the cosmic rays, their age t must be less than $3 \times 10^6/\rho$ years.

FRIDAY AFTERNOON AT 15:00

Minería

(C. D. ANDERSON presiding)

Cosmic Rays, II; Atmospheric Physics

L1. Penetrating Showers in Carbon.* JOHN R. GREEN AND W. B. FRETTER, *University of California at Berkeley.*—Penetrating showers produced in carbon in a cloud chamber containing carbon and lead plates[1] have been analyzed and compared to the penetrating showers produced in lead in the same cloud chamber when it contained only lead plates.[2] Similarity in angular distribution of lightly ionizing secondary particles indicates that the events observed in the two experiments are of the same average energy. When necessary geometrical corrections are made, a value of 3.2 to 3.6 penetrating particles per event is obtained from carbon; the corresponding value from lead is 3.8. Multiplicities of observed penetrating particles up to ten were obtained for single events in carbon plates. The similarity of events in carbon and in lead suggests multiple production of mesons. Associated production of electronic cascade showers can be explained by assuming that they are produced by high energy gamma-rays originating near the parent event. The mean free path of lightly ionizing secondaries of the penetrating showers for subsequent production of nuclear events is found to be 237 ± 29 g/cm² of carbon.

* Assisted by the joint program of the ONR and AEC.
[1] John R. Green and W. B. Fretter, Phys. Rev. **78**, 92 (1950).
[2] W. B. Fretter, Phys. Rev. **76**, 511 (1949).

L2. Improved Calculations on Cascade Shower Theory. IRA BERNSTEIN, *Brookhaven National Laboratory.**—Snyder[1] has recently given solutions of the diffusion equations of cascade shower theory of such a nature that accurate numerical calculations of the average number of particles at a given depth in an absorber are readily derivable therefrom. He used, however, the so-called completely screened cross sections for pair production and bremsstrahlung. These assign too large a value to the elementary processes associated with low energy particles, though they are accurate for high energy particles. By writing the diffusion equations as a single integral equation an iteration scheme has been developed, which permits introduction of more accurate cross sections. The first approximation is taken to be the Snyder solution. The first iteration on this yields a correction to the Snyder result which indicates that the shower maximum is decreased by ten or more percent, and that there is a decrease in the average number of particles at small depths, with a corresponding increase for large. The results are quantitatively accurate only for light elements and moderate initial energies.

* Work performed at Brookhaven National Laboratory under contract with AEC.
[1] H. S. Snyder, Phys. Rev. **76**, 1563 (1949).

L3. Neutron Production by Cosmic Rays at Three Depths.* R. D. SARD, *Washington University.*—Further measurements by the Washington University cosmic-ray group on neutrons associated with charged cosmic-ray particles will be reported. With apparatus of the type previously described,[1] measurements have been made at Climax, Colorado[2] (3400 m), St. Louis (160 m), and in the sub-basement of a St. Louis skyscraper under 1000 to 1500 g cm^{-2} of material. The changes of the various coincidence rates with depth are used to separate neutron production by μ-mesons from neutron production by nucleons (or their π-meson secondaries). The sea-level-mountain comparison indicates that most, but by no means all, of the sea-level $(AB\text{–}C:N)$ events are due to the stopping of μ-mesons, in the Pb absorber. The $(ABC:N)$ events can be ascribed to the nucleonic component. The sea-level-underground comparison indicates either that the nucleonic component is hardly more attenuated than the mesonic component at the underground site used or that there is production of low energy neutrons by fast μ-mesons. Numerical results will be presented.

* Research partially supported by the joint program of the ONR and AEC.
[1] Sard, Conforto, and Crouch, Phys. Rev. **76**, 1134 (1949).
[2] W. B. Fowler, Phys. Rev. (to be published).

L4. Cosmic-Ray Diurnal Effect Measurements. T. A. BERGSTRALH AND C. A. SCHROEDER, *U. S. Naval Research Laboratory.*—In two balloon flights at Minnesota a search was made for diurnal effects in the cosmic radiation at altitudes above 50,000 feet. Measurements were made simultaneously at the total ionizing radiation, γ-radiation in the energy range of approximate 0.08 to 5 Mev; and fast neutrons. The ionizing radiation and γ-radiation was measured by means of a central horizontal counter tube surrounded by a closely packed ring of horizontal counters. Coincidences between the central counter and the outer ring determined the ionizing radiation, while anticoincidences gave the intensity of the γ-radiation. The neutron flux was measured by two BF_3 counters, one filled with enriched BF_3, mounted side by side in a vertical paraffin cylinder eight inches in diameter surrounded by Cd. One flight was launched at 12:30 A.M. CST and remained aloft until 8:00 A.M. The other flight was launched at 6:20 P.M. and landed at 10:10 P.M. No diurnal effects were observed. The statistical accuracy of this measurement is on the order of one percent for the total ionizing radiation and on the order of 3.5 percent for the γ-radiation and neutron measurements.

L5. Barometric and Out-Door Temperature Coefficients of Frequency of Small Cosmic-Ray Bursts. JAMES W. BROXON, *University of Colorado.*—Multiple linear regression coefficients (b) and partial correlation coefficients (r) and the normal significance ratios (t) of r, have been computed for the frequency of occurrence of a class of small cosmic-ray bursts with respect to barometric pressure ($_{12\cdot3}$) and out-door temperature ($_{13\cdot2}$), for 19 individual months. This class of bursts represents (1.2 to 1.9)$\times 10^6$ ion pairs collected in a very heavily shielded spherical ion chamber of 13.3 liters effective volume containing argon at 20 atmospheres and 25°C at Boulder, Colorado, geomagnetic latitude 49°N. These occurred at an average rate of about 10 per hour. Eighteen of the 19 months displayed negative barometric coefficients. The average $b_{12\cdot3}$ for all 19 months was −1.54 percent/mm, while the average for the 10 months with $t_{12\cdot3}$ above the two percent level was −2.44 percent/mm. (The barometric coefficient for the background cosmic-ray ionization in the same chamber has a lower order of magnitude.) Fifteen of the 19 months displayed negative temperature coefficients. The average $b_{13\cdot2}$ for all 19 months was −0.98 percent/°C, while the average for the 7 months with $t_{13\cdot2}$ above the two percent level was −1.66 percent/°C.

L6. The Change of Intensity of the Nucleonic Component during Magnetic Storms. J. A. SIMPSON, *University of Chicago.*—Several measurements of the latitude dependence of the neutron and star intensities under 312 g-cm^{-2} of air between 40° and 65°N geomagnetic latitude show a flattening of the intensity curves in the region above 50°N. Two sets of these measurements followed closely the commencement of moderately severe or severe magnetic storms. In each case the intensity above 50°N showed a characteristic increase with increasing age of the storm. Following the commencement of one of the storms it was found that in a period of five days the knee of the intensity curve had shifted northward approximately 3° with a fast neutron intensity increase of six percent. No changes of intensity were observed below 47° geomagnetic latitude. It may be shown that these intensity changes were not due to longitude or temperature effects. The data indicate that the low energy cut-off for the primary radiations was decreasing with the increasing age of the magnetic storm.

L7. Correlation of Auroral Observations in the Northern and Southern Hemispheres. D. E. LITTLE AND G. M. SHRUM, *University of British Columbia.*—Studies have been made of observations of the Aurora Borealis and the Aurora Australis with a view to establishing a correlation between them. The degree of this correlation gives some indication of the effect of atmospheric conditions upon the occurrence of aurorae. The work has brought out the need for more detailed records of observations, especially in the Southern Hemisphere.

L8. Surface Ozone in Arctic Regions.* W. S. WILSON, *University of Alaska.*—The author's use of the indirect oxidation of sodium arsenite as an agent for the determination of daily average values of the concentration of ozone in the atmosphere near the surface is described. Values obtained at College, Alaska, for the first three months of 1950 are shown. These show large variations from day to day, often rising to many times the maximum value. Except for a few unusually high values which are apparently associated with special conditions in the Arctic atmosphere, the values for the concentration are on an average rising with increasing altitude of the sun. As a rule these values are less uniform and higher than those reported from stations in lower latitudes.

* This work was supported in part by contract with the U. S. Air Force, through sponsorship of the Geophysical Research Directorate, Air Materiel Command.

Post-Deadline Papers

FRIDAY AFTERNOON AT 15:00

Anfiteatro Bolívar

(R. A. MILLIKAN presiding)

Invited Papers

M1. Soil Mechanics of the City of Mexico. NABOR CARRILLO, *Comisión Impulsadora y Coordinadora de la Investigación Científica.* (20 min.)

M2. Forces on a Supraconductor in a Magnetic Field. W. V. HOUSTON, *Rice Institute.* (30 min.)

M3. Modern Developments in X-ray Crystal-Structure Analysis. RAY PEPINSKY, *Pennsylvania State College.* (40 min.)

FRIDAY AFTERNOON AT 15:00

Minería

(E. M. MCMILLAN presiding)

Artificial Mesons; Miscellany in Nuclear Physics

N1. Photo-Mesons from Carbon. J. M. PETERSON, R. S. WHITE, AND W. S. GILBERT, *University of California, Berkeley.*—The energy spectrum of negative and positive π-mesons produced in carbon by x-rays from the 330-Mev electron synchrotron in Berkeley has been measured at angles of 45°, 90°, and 135° to the beam axis using C-2 nuclear emulsions. The carbon target was a sphere of 0.620-inch diameter, approximating a point source. The meson detection system employed completely poor geometry; the nuclear plates were imbedded in a massive cylinder of copper surrounding the target. The minus-plus ratio has no statistically significant variation with energy; the average over energy appears to be independent of angle and equal to about 1.35 ($\pm$0.15 at 90° and 135°, $\pm$0.2 at 45°). The energy spectra characteristically have broad

maxima in the region from 30 to 70 Mev and fall to zero in the region from 100 to 150 Mev, the exact behavior depending on the angle. More mesons are emitted at 135° and at 90° than at 45°. The total cross section is about 3×10^{-28} cm² per nucleus per quantum. This work was supported by the United States AEC.

N2. Photoproduction of Mesons from Hydrogen. A. S. BISHOP, J. STEINBERGER, AND LESLIE J. COOK, *University of California, Berkeley.*—Using the delayed coincidence technique[1,2] for detection of artificially produced mesons, we have measured the energy distribution of π^+-mesons from hydrogen. These mesons are formed when the x-ray beam from the 335-Mev electron synchrotron strikes a liquid hydrogen target. Since the photons are completely absorbed in the process of meson creation, there is an exact relationship (for a given angle of emission of mesons) between the energy of the meson and the energy of the photon responsible for its creation. Thus, using the measured energy distribution of the mesons at 90°, and the energy distribution of the photons from the synchrotron, we have determined the excitation function for photoproduction of mesons at 90°. This function increases rather slowly and flattens off for photon energies above about 280 Mev. This work was performed under the auspices of the AEC.

[1] F. Rasetti, Phys. Rev. **60**, 198 (1941).
[2] J. Steinberger and A. S. Bishop, Bull. Am. Phys. Soc. **25**, 11 (1950).

N3. Positive Mesons Produced by 345-Mev Protons in Liquid Hydrogen. VINCENT Z. PETERSON, *University of California, Berkeley.*—The production of mesons in proton-proton collisions has been studied directly using the photographic technique by bombarding a liquid hydrogen target with 345-Mev protons. A "point" source having 0.002-in. Al walls contains the hydrogen, and plates imbedded in copper absorbers are placed at various angles with respect to the beam. Earlier experiments[1] having shown that only positive mesons are produced, a bending magnet has been interposed between target and detector to separate mesons from elastically scattered protons. Exposures made at $30\pm1\frac{1}{2}°$ show an improvement in mesons-to-background of about 100. The sharp peak near the higher end of the meson energy spectrum,[1] indicating a strong interaction between the outgoing nucleons, has been obtained with much better statistics. However the energy resolution was still insufficient to determine whether or not a real deuteron is formed in the process. Further experiments at $15\pm\frac{3}{4}°$ designed to improve the energy resolution at the upper end of the spectrum, until limited only by the energy spread of the primary beam (~2 Mev), are now in progress and will be reported. This work was performed under the auspices of the AEC.

[1] Post-deadline paper by the author at the Washington, D. C. meeting.

N4. D−He⁴ Interaction for 10.3-Mev Deuterons. JOHN C. ALLRED, DAROL FROMAN, ALVIN HUDSON, AND LOUIS ROSEN, *Los Alamos Scientific Laboratory.*—A multiple nuclear plate camera[1] has been utilized to make simultaneous observations of the range and intensity distribution of the products of the D−He⁴ reaction for 10.3-Mev deuterons from 18.4° to 158.6° (center of mass). The externally focused beam from the Los Alamos cyclotron was used for these experiments. There is evidence for a sizable cross section for the reaction $D+He^4\rightarrow He^4+n+p-2.2$ Mev. The differential elastic scattering cross-section curve shows marked anomalies. The elastic scattering cross section in millibarns for some of the CM angles investigated are: 22.0°, 371±13; 29.4°, 192±7; 43.8°, 57±2; 51.0°, 22±1; 55.4°, 10.5±0.4; 58.4°, 9.8±0.4; 69.4°, 21.7±0.9; 78.8°, 39.6±1.4; 85.4°, 58±2; 97.7°, 69.1±2; 110.6°, 58.7±2; 120.6°, 41.8±1.5; 124.6°, 37.8±1.3; 129.3°, 37.0±1.6; 137.8°, 40.0±1.4; 147.4°, 52.2±2.6; 155.4°, 73±7; 157.4°, 82±8.

[1] J. C. Allred and Louis Rosen, Bull. Am. Phys. Soc. **25**, No. 3, 36 (1950), abstract Q4.

N5. Transmutation of N¹⁵ by Protons. A. W. SCHARDT, W. A. FOWLER, AND C. C. LAURITSEN, *California Institute of Technology.*—Measurements have been made from 0.2 to 1.6 Mev of the cross sections of the reactions (1) $N^{15}(p\alpha)C^{12}$, (2) $N^{15}(p\alpha')C^{12*}(\gamma)C^{12}$, and (3) $N^{15}(p\gamma)O^{16}$. The second reaction involves the well-known level in C¹² at 4.5 Mev. The gamma-rays from (2) and (3) were separated by coincidence absorption measurements. All three reactions show marked resonances. Preliminary results for the resonance widths and for the cross sections (10^{-24} cm²) are tabulated.

E_R (Mev)	Γ (kev)	σ_1	σ_2	σ_3
0.36	~100	0.1		
0.429	<0.8		0.2	
0.899	2		0.6	
1.0	~160	0.5	0.002	0.0005
1.21	20	0.6	0.2	

This work was assisted by the joint program of the ONR and AEC.

N6. A Study of the $N^{14}(p,\gamma)O^{15}$ Reaction.* D. B. DUNCAN† AND J. E. PERRY, JR., *California Institute of Technology.*—The cross section for the transmutation of nitrogen by protons has been investigated using an electrostatic generator. Excitation curves have been obtained up to 2.7 Mev from the bombardment of thick Be_3N_2 targets, nitrogen gas targets of various thicknesses, and a thin target formed by proton bombardment of a copper foil in a nitrogen atmosphere. Properties of the observed resonances are tentatively summarized.

E_R (Mev)	0.277[1]	1.065	1.550	1.748	1.815	2.356	2.489	
$Y_{max}(\infty)$	0.4	6	1	1.5	4	15	20	all $\times10^{-10}$
$\omega\gamma$ (ev)	0.02	0.6	0.2	0.2	0.5	2	3	
Γ (kev)	<2[1]	5	50	11	7	14	11	
σ_R (cm²)	—	3.5	0.06	0.3	1	2	3.5	all $\times10^{-28}$

These resonances are superimposed on a non-resonant yield whose cross section is 0.4, 3, 6×10^{-29} cm² at 1, 2, and 2.5 Mev respectively. Extrapolation of these yields to low energies indicates that the non-resonant reaction is dominant in the Bethe sun cycle.

* This work was assisted by the joint program of the ONR and AEC.
† AEC Predoctoral Fellow.
[1] Tangen, Kgl. Nord. Vid. Sels. Skr. No. 1 (1946).

N7. Excited States of N¹³ and C¹³. R. G. THOMAS,* *California Institute of Technology.*—If *nn* and *pp* nuclear forces are equal, corresponding excited states should be found in light mirror nuclei. In comparing low energy levels of C¹³ with those of N¹³ it must be considered that the levels in N¹³ are in the continuum, and that the amount of time the proton spends outside of the nucleus with a diminished Coulomb interaction depends on the reaction width. The states at 2.37 and 3.52 Mev in N¹³ are compared with those at 3.10 and 3.91 Mev in C¹³. The large width-without-barrier of the first state in N¹³ suggests an *s*-wave reaction[1] and a large level shift. By applying Green's theorem to the neutron wave function in C¹³ and the proton wave function in N¹³ and using the resonance theory of Feshbach, Peaslee, and Weisskopf or Wigner and Eisenbud, the level shift can be calculated in terms of logarithmic derivatives at the nuclear surface and the reaction width. Taking into account nuclear expansion with excitation, level shifts are calculated which are in reasonable agreement with observation.

* AEC Predoctoral Fellow.
[1] Fowler, Lauritsen, and Lauritsen, Rev. Mod. Phys. **20**, 236 (1948).

N8. The Fission Yield Curve of Th²³² with Pile Neutrons.* J. NIDAY AND A. TURKEVICH, *Argonne National Laboratory* and the *University of Chicago.*—The relative yields of nineteen products of thorium fission with mass numbers between 72 and 144 have been determined radiochemically. The thorium was irradiated in the center of the Argonne heavy water pile,

the effective neutrons probably having not much more than the threshold energy. Most of the yields determined were on the light side of mass 116. A complete fission yield curve was drawn assuming all the fissions are binary and assuming, arbitrarily, that two neutrons are emitted. Thorium fission is similar to slow neutron fission in being highly asymmetric. The peak yields occur 120±20 times as frequently as symmetrical products. As has been noted previously, the main effect of varying the mass of the fissioning nucleus (e.g. Pu^{239} cf. Th^{232}) appears to be to shift the light peak, the heavy peak tending to occur in the same mass region.

* A few of these results were presented before the Chicago meeting of the AAAS (December, 1947).

N9. Precise Determination of the Ratio of the Deuteron to Proton Magnetic Moment. B. SMALLER, E. YASAITIS, AND AND H. L. ANDERSON.—A precision determination has been made of the ratio of the deuteron to proton nuclear magnetic moment utilizing the Purcell method of resonance nuclear induction. A unique method of synchronization has resulted in high stability of both H and D patterns with respect to each other, and has minimized the need for ultra-precision in oscillation frequency and stability. Simultaneous measurements of ν_H and ν_D on the same D_2O–H_2O sample have removed the need for high field homogeneity over a region greater than the sample area. The widths of the H and D resonance lines were 0.018 gauss and 0.048 gauss respectively in a field of 7200 gauss. The relative error in frequency ratio determination that could be achieved was less than 5×10^{-8}. Measurements on 5 different samples having different Mn^{++}/D^{+} concentration ratios ($10^{-4}\rightarrow0$) gave $\mu_H/\mu_D=3.25720037\pm0.00000056$.

N10. Production of Deuterium-Zirconium Targets. J. J. MOORE AND R. N. LITTLE, *The University of Texas.*—Deuterium-Zirconium targets[1] for use in the reaction D_2 on D_2 have been produced in which two different methods of heating the zirconium metal target to outgas it have been used. By one method the target was heated by electrical conduction through the metal and in the second method by direct bombardment of the metal target with electrons, using the target as the plate of a vacuum tube. An attempt is being made to put the production of these targets on a semimass production basis. Tritium targets will also be produced in the same manner upon the receipt of tritium gas. Results concerning yield of neutrons and decay in yield of neutrons due to use will be given.

[1] Graves, Rodrigues, Goldblatt, and Meyer, Rev. Sci. Inst. **20**, No. 8, 579–582 (1949).

FRIDAY AFTERNOON AT 15:00

Minería

(L. I. SCHIFF presiding)

Nuclear Theory

O1. The Energy Levels of Atomic Nuclei. H. A. WILSON, *Rice Institute.*—Nearly 200 energy levels, between 0 and 5 Mev, have been reported for about 40 different nuclei. These levels have been arranged in order of magnitude and a graph drawn showing the magnitudes against the order numbers. The graph shows a series of rounded off steps showing that there is a series of levels each belonging to several different nuclei. The levels at the steps are 4.80, 4.40, 4.00, 3.65, 3.50, 3.30, 3.00, 2.80, 2.55, 2.40, 2.00, 1.65, 1.25, 0.80, 0.65 Mev. Eleven of these 15 levels are nearly equal to values of $E_n=0.387((n-1)(n+2))^{\frac{1}{2}}$ Mev with n equal to the integers from 12 to 2. These values of E_n are 4.80, 4.41, 4.02, 3.63, 3.24, 2.84, 2.45, 2.05, 1.64, 1.22, 0.77 Mev. According to the spherical shell nuclear model proposed by the writer all nuclei should have vibration levels equal to E_n. The graph shows that only a few of the nuclei have each value of E_n. This means that when nuclear levels are observed usually only a few of the possible levels actually appear. The levels 3.50, 3.00, 2.55, 0.65 are probably rotation-vibration levels.

O2. Nuclear Saturation and Magic Numbers in Terms of a Non-Linear Meson Theory. L. I. SCHIFF, *Stanford University.*—A non-linear term corresponding to contact repulsion between mesons is expected to: (1) provide a many-nucleon interaction that leads to nuclear saturation without repulsive interactions in odd l states; (2) provide a sounder physical basis for the single-nucleon model that leads to shell structure and magic numbers. The relatively slow increase of meson density with increasing nucleon density causes: (1) the kinetic energy per average nucleon to increase more rapidly than the potential energy for high density; (2) the potential energy of a nucleon to depend less on its immediate neighbors than on the average nucleon density in its vicinity. For such a neutral scalar meson in free space, plane wave solutions of the classical field equation are found, but localized static solutions do not exist. The meson source functions associated with nucleons must be extended in space; the divergent parts of the total energy (nucleon self-energy) are additive and can be eliminated. A variation principle gives an upper bound for the energy, and is being used to calculate the two-nucleon interaction. A crude model of a heavy nucleus, in which the source density is constant, gives reasonable results for the binding energy and volume per nucleon.

O3. Boundary Conditions for the Description of Nuclear Reactions. M. MOSHINSKY, *Institutos de Física y Geofísica, Universidad de México.*—A phenomenological description of nuclear reactions by means of appropriate boundary conditions, will be proposed. The several stages of the reaction (initial particles, compound nucleus, etc.) are described in their respective configuration spaces, and the state representing the nuclear reaction is given by a wave function of the type introduced by Fock.[1] The wave equations satisfied by the Fock wave function, are deduced with the help of an analogy with vibration problems. We find that the interactions leading to the nuclear reaction can be expressed as boundary conditions between the different components of the Fock wave function taken at the point of coincidence of the particles. A discussion is given of elastic scattering and two particle nuclear reactions, showing that this procedure gives the same dependence of the cross sections on energy as the Breit-Wigner resonance formula and its generalizations. With the help of appropriate wave functions in n-particle configuration space, the present procedure can be be extended to the description of multiple particle nuclear reactions. The energy distribution between the particles produced in the reaction has been investigated, and the results

are compared with known multiple particle disintegrations such as β-decay.

[1] Fock, Zeits. f. Physik **622**, 75 (1932).

O4. Normal Modes of Vibration of Nuclei. I. BLOCH, *Vanderbilt University.*—The force between two nuclear particles is idealized as a linear function of the particles' separation. In the absence of spin-orbit interaction, the Hamiltonian can then be separated by transformation to normal coordinates; the Schrödinger equation for a nucleus containing A particles is equivalent to $3A$ separate equations, one for each of the $3A$ normal modes of vibration. Three of these equations together have a plane-wave solution which describes the motion of the center of mass. The parameters in the remaining $3(A-1)$ equations depend on the spins and isotopic spins of the nucleons; each equation is of the type which applies to a linear harmonic oscillator. The nucleus described by such a set of equations has infinite binding energy, but may nevertheless behave in some ways like actual nuclei. Furthermore, for the lowest energy levels, the linear forces may be "cut off" at some finite distance by means of a perturbation calculation.

O5. Scattering of Mesons by Nucleons. ALEJANDRO MEDINA, *Universidad Nacional de México.*—The scattering of mesons by free and bound nucleons is considered and the scattering cross section determined assuming different types of coupling and including radiative corrections. Using fundamentally Schwinger's methods, a procedure is devised whereby the cross section can be directly obtained.

O6. On the Self-Energy of Mesons. FERNANDO PRIETO, *Universidad Nacional de México.*—Using Schwinger's well-known method, the self-energy of a meson in interaction with a nucleon field has been considered, extending Matthews calculations[1] to other types of coupling. Mass renormalization factors are in each case determined and following Dyson[2] the elimination of the self-energy terms is effected.

[1] P. T. Matthews, Phys. Rev. **76**, 1657 (1949).
[2] F. J. Dyson, Phys. Rev. **75**, 486 (1949).

O7. Polarization of Vacuum by Meson Fields. JUAN DE OYARZABAL, *National University of Mexico.*—Calculations have been performed on the polarization of a matter vacuum due to a meson field. Using Schwinger's method,[1] the induced current in vacuum has been evaluated assuming different types of coupling. The effect of vacuum polarization on the interaction between mesons has also been considered. This work is an extension of Case's[2] calculations.

[1] J. S. Schwinger, Phys. Rev. **75**, 651 (1949).
[2] K. M. Case, Phys. Rev. **76**, 1 (1949).

O8. Spin-Orbit Interactions and Nucleon-Nucleon Scattering. K. M. CASE AND A. PAIS, *Institute for Advanced Study.*—It will be shown that the Berkeley data on n-p and p-p scattering may be interpreted in a charge independent theory utilizing a spin-orbit (LS) interaction of the kind familiar from atomic physics. An LS coupling does not affect low energy phenomena. The contribution to the cross-section is proportional to $\sin^2\theta$ and thus favors 90° scattering. At this angle the LS scattering is four times as large for p-p as it is for n-p. A strongly singular spatial dependence suffices for a simultaneous description of the 30 and 350 Mev p-p experiments. It is important for the n-p case that the P scattering caused by the LS term does not interfere with S scattering due to central forces. Hence the interpretation of n-p scattering by Christian and Hart is essentially unaffected. General considerations on the bound state of the deuteron fix the sign of the coupling so that for given orbital angular momentum the state of largest j lies lowest. This, as well as the magnitude, is suggestive in connection with Goeppert-Mayer's interpretation of the shell model for heavy nuclei.

FRIDAY EVENING AT 20:00

Salón de los Candiles, Hotel del Prado

(I. I. RABI presiding)

Banquet of the American Physical Society

After-Dinner Speakers

Scientific Cooperation in Action. MANUEL SANDOVAL VALLARTA, *El Colegio Nacional e Instituto de Física, Universidad de México.*

Title to be announced. E. U. CONDON, *National Bureau of Standards.*

SUPPLEMENTARY PROGRAMME

SP1. Motion of Charges in Magnetic Fields. A. ROMERO JUAREZ, *Instituto de Física, Universidad de México.*—The motion of a charged particle in a static purely magnetic field is characterized by the fact that the curvature κ of the orbit at every point is proportional to the magnitude of the force. Plane motion is considered. If the field H depends only on the distance r to a fixed point, the trajectory can be obtained in a simple manner. To do this we notice the following property of a plane curve: if κ depends only on r, the polar equation of the curve can be found by means of quadratures only. The results are applied to the following cases: (a) Superposed dipole and constant fields. The solution involves automorphic functions of genus 2. When the constant field vanishes, one gets the equation of the orbits in the equatorial plane of a magnetic dipole and it is possible to express it in terms of elliptic functions. (b) Magnetic field proportional to $1/r$. Only elementary functions appear in this case. The more general case in which H varies as $1/r^n$ is examined and values of n are determined for which the problem is soluble in terms of given functions.

* To be given at the end of Session H if the Chairman rules that time permits.

SP2. Multipole Order of the 3.1-Mev Gamma-Ray from Carbon 13.* R. G. THOMAS,† *California Institute of Technology.*—There is evidence that the radiation from the 2.37-Mev state in N^{13} is electric dipole. A determination of the

multipole order of the radiation from the state at 3.1 Mev in the mirror nucleus C^{13} is of interest as a check on the possible correspondence of these two levels. A magnetic lens spectrometer was used to measure the intensity of the gamma-radiation and internally formed positrons from this state produced in the reaction $C^{12}(d, p)C^{13*}$. Gamma-ray intensity was determined from photoelectric conversion in thorium and Compton conversion in thin and thick aluminum foils; polarization effects and straggling in energy loss were considered in calculating the electron stopping cross section required for the thick converter method. The observed pair formation could be compared with the theoretical energy distribution given by Rose only over the high energy portion of the positron spectrum which was free from the effects of extraneous radiations. For electric dipole radiation the agreement is within 10 percent, the estimated experimental error; the deviation would be greater than 60 percent for other radiation multipoles. This work was assisted by the joint program of the ONR and AEC.

* To be given after Session N if the Chairman rules that time permits.
† AEC Pre-doctoral Fellow.

SP3. The Interaction of Birkhoff's Gravitational Field with the Electromagnetic and Pair Fields.* M. MOSHINSKY, *Institutos de Física y Geofísica, Universidad de México.*—The flat space-time theory of gravitation proposed by G. D. Birkhoff is discussed from the standpoint of a field theory, and in particular, the interaction of Birkhoff's field with other fields is developed. This interaction is shown to take place through the interaction Lagrange function $h_{\mu\nu}\Theta_{\mu\nu}$ where $h_{\mu\nu}$ is the symmetric tensor potential describing the gravitational field and $\Theta_{\mu\nu}$ is the symmetric energy momentum tensor of the external field. With the help of this interaction Lagrange function, the action of the gravitational field on the electromagnetic and pair fields can be established, and shown to lead to a modification of Maxwell and Dirac equations. These modified equations determine a change in the index of refraction and a shift of the energy levels of the atom, which account for the bending of light and the red shift, respectively, in gravitational phenomena. Furthermore, the effect of an external gravitational field on the Dirac equation leads to a gravitational correction to the magnetic moment associated with the spin and orbital motion of the electron. The correction of the spin magnetic moment of the electron, due to the gravitational field of the star or planet on whose surface it is found, is $-M/R$ Bohr magnetons, where M is the mass of the star in relativistic units, and R the radius in cm. On the surface of the earth the correction is therefore $\simeq 10^{-9}$.

* To be given after Session G if the Chairman rules that time permits.

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Simpson, J. A.—No. L6
Singer, S. F. and J. A. Van Allen—No. K6
Smaller, B., E. Yasaitis, and H. L. Anderson—No. N9
Stickley, E., M. M. Newman, and J. D. Robb—No. H4
Thomas, R. G.—No. N7, SP2
Tyson, J. K.—No. H6
Vallarta, M. S.—No. E1
Van Allen, J. A. and S. F. Singer—No. K5
Webb, Lyman A., Ronald S. Paul, and Francis E. Dart.—No. H9
Wilson, H. A.—No. O1
Wilson, W. S.—No. L8
Winckler, J. R.—No. E2
Wu, Ta-You and L. Ourom—No. H11

The American Physical Society

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Please cut along this line

(To be sent by air mail to Dr. M. S. Vallarta, Comision Impulsora de la Investigacion Cientifica, Puente de Alvarado 71, Mexico, D. F., Mexico).

I EXPECT to attend the dinner of the American Physical Society at twenty o'clock on Friday evening, June 23. My party will comprise .... persons.

(*Name*).....